

Ambient Air Monitoring

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California Environmental Protection Agency
Air Resources Board

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100 INTRODUCTION

Ambient Air Monitoring

The Compliance Assistance Program (CAP) is an effort by the California Air Resources Board (CARB) to provide assistance to local air pollution control districts in conducting more comprehensive, consistent, and accurate compliance inspections; and to provide industry with information and tools to attain and remain in compliance with federal, state, and district rules and regulations. By assisting industry and local districts in compliance determinations, CAP intends to reduce emissions to the air and improve industry compliance rates.

The CAP produces user-friendly documents targeted to identified needs of specific audiences. These documents include technical manuals (as this document is), handbooks (often referred to as "comic books" due to their informal style), and quick reference pamphlets.

This manual is intended as a dynamic document to assist with the highly technical and rapidly changing field of ambient air monitoring. As the state of the technology advances, and as the regulatory environment changes, this manual will be periodically updated. Additionally, updates to this manual rely on the user to identify important issues. As you read the manual, please send your comments and proposed revisions and amendments to:

Air Resources Board
Compliance Division, Compliance Assistance Section
P.O. Box 2815
Sacramento, CA 95812

When you first receive this manual, or if the manual changes hands, please be sure to fill out the tracking card located in the front of the manual and **promptly mail it to the ARB**. The tracking cards also are used to keep us up to date of any address changes. Revision of the manual are distributed to the registered holder of the manual, based on our records from the tracking cards.

The organization of this manual is divided into chapters relevant to the basic information and regulations about ambient air monitoring (Section 100), a detailed overview of the important fundamentals of monitoring (Section 200), air monitoring standards and programs (Section 300), station siting, configuration, and instrumentation (Sections 400, 500, and 600 respectively), and a discussion of data handling, documentation, and quality assurance (Sections 700, 800, and 900.) A glossary contains important terms, equations, units, and conversion factors. Finally, the appendices contain important additional information, including the text of pertinent regulations (current as of this writing) and

100 INTRODUCTION

a series of forms that can be copied and/or modified for use in developing and inspecting monitoring programs.

101 INTRODUCTION TO AMBIENT AIR MONITORING

The atmosphere is a complex and dynamic entity. The current composition and structure have evolved in tandem with the evolution of the earth (e.g., geographic and geological) and life on the earth.

It is believed that the atmosphere was originally formed about five billion years ago.¹ In the first 500 million years a dense atmosphere of hydrogen, water vapor, methane, and carbon dioxide emerged. Prior to 3.5 billion years ago the atmosphere probably consisted of carbon dioxide, carbon monoxide, water, nitrogen, and hydrogen. The hydrosphere was formed about four billion years ago from the condensation of water vapor, resulting in oceans of water in which sedimentation and aqueous chemistry occurred. The most important feature of the ancient atmosphere was the absence of free oxygen.

Geological processes that may sequester chemicals in sediment or release them through volcanic processes changed the prebiotic atmosphere. However, the greatest changes occurred after the origins of life. The current oxidizing atmosphere is generally attributed to the evolution of photosynthesis.

Although geological and biological processes can be looked upon as 'polluting' the original atmosphere, those effects also can be viewed as natural and apart from the anthropogenic pollution effects that we are interested in this manual. Human activities can be seen to be having significant effects on the natural physical and biological systems, causing rapid changes in those systems with human health and welfare as well as ecological impacts.

A major difference between the natural and anthropogenic processes is the time over which they have occurred and affected the atmospheric content. The natural process typically takes many thousands or millions of years to occur. The anthropogenic processes, on the other hand, have only occurred in the last several thousand years, with the greatest impact in only the last 100-150 years.

101.1 HISTORY OF AMBIENT AIR MONITORING

Air pollution, as an anthropogenic phenomenon, has existed since the first cave man kindled the first fire. With the advent of the bronze age, industrial type

emissions began with the advent of metals smelting. Ice in the Greenland ice sheet records arsenic and lead from metalworking in the sixth century B.C.

Historically, air monitoring, as a scientific process, can be dated to the mid-nineteenth century. In 1840 C.F. Schoenbein^{2,3} published an article about a monitoring technique for measuring ozone. The monitoring technique was quite simple: a paper strip was embedded with a paste of KI and starch which turns blue on exposure to ozone. After 12 hours of exposure, the amount of ozone can be determined by comparison to colors on a reference test chart and recorded as Schoenbein (0 - 10) or Salleron (0 - 21) units. A more discriminating method using arsenic potash was in use by about 1876. Recent evaluation of data from nineteenth century studies² using these methods in Paris and Michigan indicate about 16 to 20 parts per billion by volume (ppbv) ozone.

By 1912, absorption of ultraviolet (UV) light with a photographic plate as the detector was being used to measure ozone in the laboratory. Ambient measurements in Paris using this method gave results of 42 ppbv. Recent reanalysis of the original photographic plates suggests a value closer to 20 ppbv, consistent with other measurements.

Infrared spectrographic methods became available by the 1940's. Adel² used the solar infrared spectrum to measure N_2O and Migeotte to measure CH_4 . In 1949 Adel and Migeotte were involved in a dispute over the measurement of CO. The dispute can largely be laid to the fact that Adel was working in the clean air in Arizona while Migeotte was working in the industrial areas of Ohio.

The early spectrographic methods used photographic plates as the detector. Quantifying the concentrations was quite difficult at the time due to the lack of computers. The plates contain excellent, highly detailed spectra that can now be reanalyzed using differential optical absorption spectrographic (DOAS) computer analysis.

In the 1940's electronic photomultiplier tubes were developed and replaced film as the detector of choice. The electronic detectors allowed for increased signal strength and reduced interference, but information about other gases was lost. The wide band spectral measurements recorded on photographic film are useful today in post hoc recalculating past concentrations and determining pollutant trends.

100 INTRODUCTION

Most instruments used in ambient monitoring today use photomultiplier tubes to measure the specific pollutant wavelength of interest. However, with the advent of the capability of computer analysis, wide-band spectroscopic methods are becoming increasingly important. In the future, narrow-band specific instruments may be used primarily for tactical reasons.

The range of spectroscopic techniques is broadly categorized by wavelength: DOAS in the UV and visible, tunable-diode lasers (TDL) in the near- and mid-IR, and Fourier transform spectrometers (FTS) in the mid-IR. These techniques will be discussed in the instrumentation chapter (Chapter 400) of this manual.

To make sense of air quality and emission trends it is necessary to first establish when that pollutant gained sufficient notoriety to be deemed an air pollutant in need of control.⁴ Prior to this time of recognition (t_r) reductions of the pollutant can be attributed to economic factors or happenstance. The t_r for SO_2 can be set at about 1950, at about the time of the 1948 Donora, PA and 1952 London fog episodes. California recognized ozone and its precursors in the 1950's; however, recognition in most other areas did not occur until the 1960's or early 1970's.

101.2 GENERAL OBJECTIVES OF AMBIENT AIR MONITORING

The objective of air pollutant monitoring is to guide the formation of policies to mitigate the effects of human activities. Ambient air monitoring, pollutant effects, management plans, and emission sources can be seen to be a set of interrelated functions (Figure 101.1.)

Monitoring activities can be divided into three categories designed to answer fundamentally different (but interrelated) questions:

- Source monitoring - What enters the environment (see CAP Manual: *Continuous Emission Monitors*)?
- Ambient monitoring - What concentrations of pollutants are present in the air?
- Effects monitoring - What are the consequences of these pollutants for humans, animals, plants, and materials?

This manual will cover the basic principles, practices, and regulations of ambient air monitoring. Source monitoring is covered in the CAP *Continuous Emission Monitoring* manual and an upcoming *Source Testing* CAP manual. Moni-

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Ambient Air Monitoring

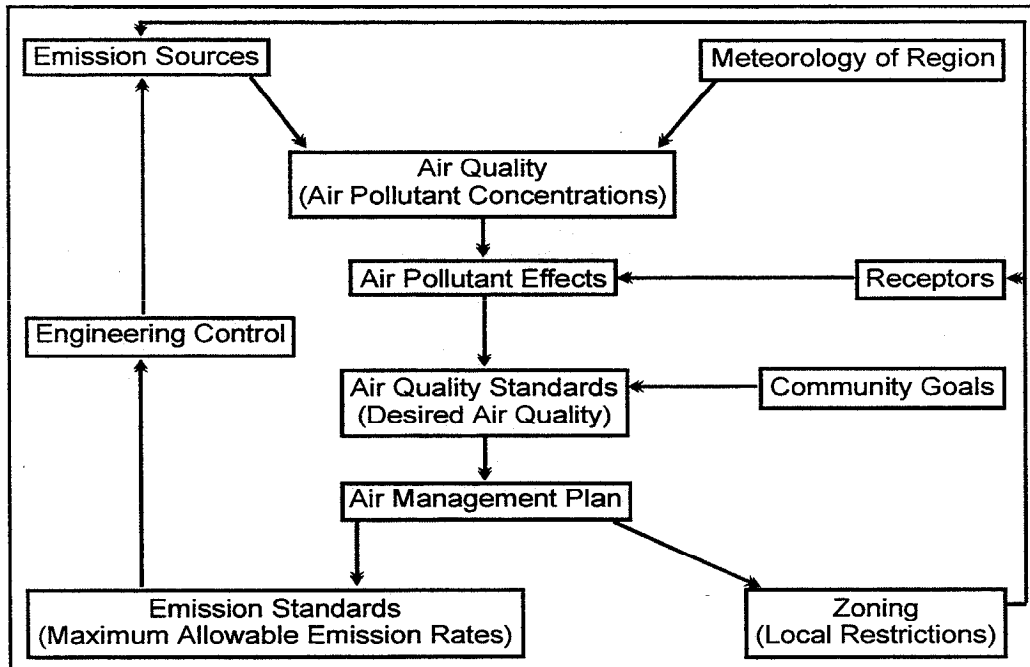


Figure 101.1 Relationships of ambient air quality, air quality management programs, and emission sources⁵

toring of the effects of air pollutants is primarily conducted by the U.S.EPA and under research grants for studies of specific effects. Few state and local agencies routinely monitor the effects of air pollution.

102 REGULATIONS

Rules and regulations at the federal level (U.S.EPA), state level (California Air Resources Board), and district level all have provisions requiring and regulating ambient monitoring.

102.1 U.S.EPA REGULATIONS

- 40 CFR 50: Contains the requirements of the National Ambient Air Quality Standards (NAAQS)⁶
- 40 CFR 53: Contains the ambient air monitoring reference and equivalent methods⁷

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- 40 CFR 58: Contains the monitoring criteria and station configurations⁸
- 40 CFR 51.24: Contains the ambient air monitoring required in association with the preventions of significant deterioration (PSD)⁹

102.2 CALIFORNIA AIR RESOURCES BOARD REGULATIONS

The regulations for ambient air monitoring in California are contained in the California Health and Safety Code.¹⁰ The Air Resources Board has also produced a six volume quality assurance manual.

- Volume I: Quality Assurance Plan
- Volume II: Standard Operating Procedures for Air Quality Monitoring
- Volume III: Laboratory Standard Operating Procedures for Ambient Air Samples
- Volume IV: Air Quality Data Processing
- Volume V: Audit Procedures for Air Quality Monitoring
- Volume VI: Standard Operating Procedures for Stationary Source Emission Monitoring and Testing

Of these manuals, Volumes I, III, V, and VI are currently to be viewed and downloaded available via the ARB's internet web pages. The rest will soon also be electronically available.

102.2.1 Health and Safety Code, Part 2, Chapter 3⁹

39601 (c): This section states that the California Air Resources Board shall adopt standards to provide a decent home and a suitable living environment.

39606 (a): The state shall be divided into air basins based on similar meteorological and geographic conditions and with consideration for political boundary lines whenever practicable. The state is currently divided into 15 air basins (Figure 102.1).

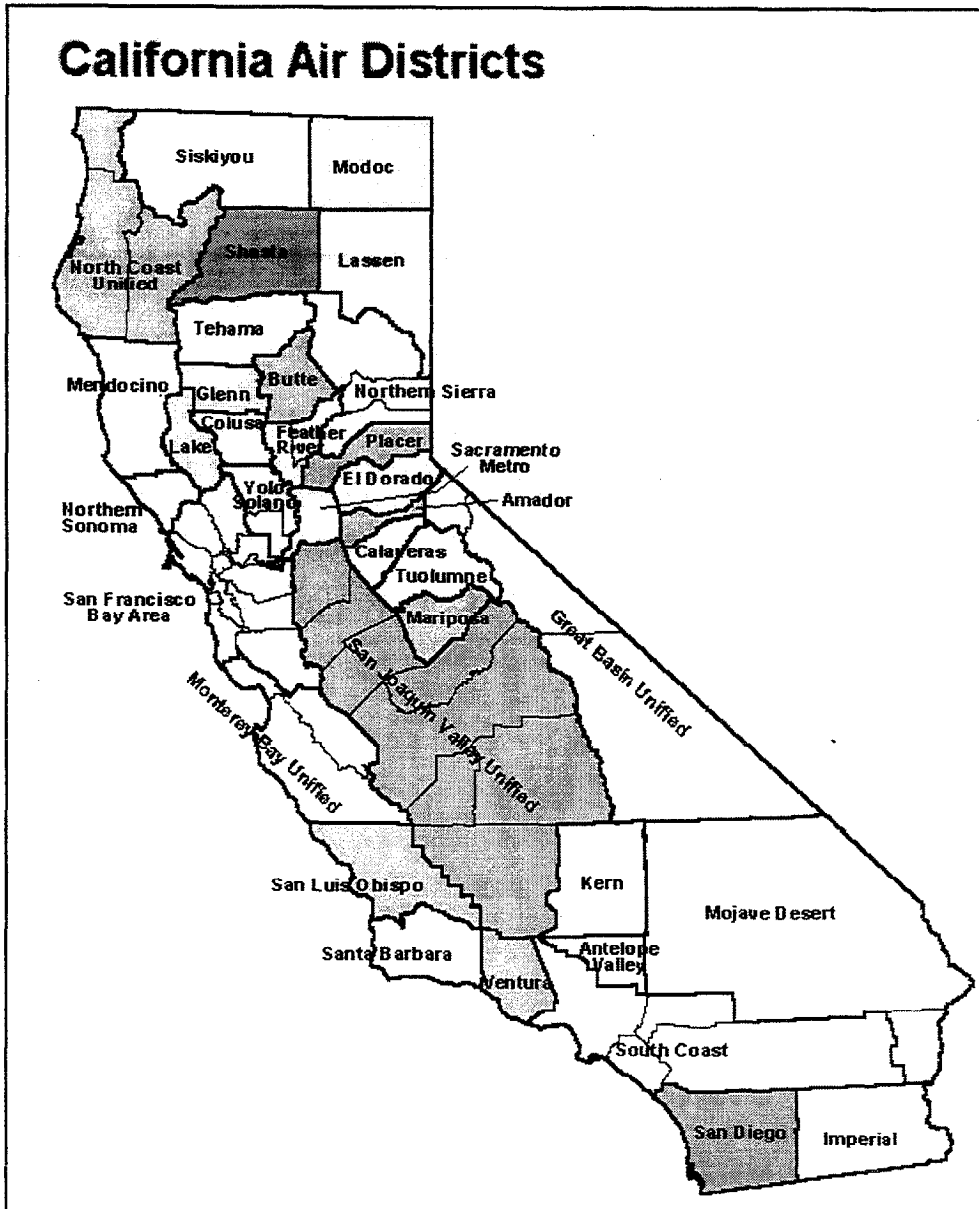


Figure 102.1 California Air Basins

39606 (b): The standards shall be based on: public health, safety, and welfare including, but not limited to: health, illness, irritation to the senses, aesthetic value, visibility, and economy. This provision also states that the standards may vary from basin to basin.

39607: This section requires the establishment of air monitoring in each air basin in cooperation with the districts and other pertinent agencies. This section

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also requires the establishment of criteria for designating attainment and nonattainment areas and air quality indicators to measure progress toward attainment.

39608: This section requires that attainment, nonattainment, and unclassified area be established for each pollutant. These areas must be reviewed annually and updated as new information becomes available.

39610: This section requires the identification of upwind areas that impact downwind air basins and an assessment of the relative contribution of the upwind basin on the downwind basin. Section 40912 of Chapter 10 requires that the upwind district formulate plans to mitigate the effects of transported air pollutants from the upwind district into the downwind district.

39660(f)(4): This section requires information on actual exposures to toxic substances determined by analytical methods that measure the dispersion and concentrations of the substances in ambient air.

Chapter 6 (39900 - 39905): Chapter 6 of Part 2 of the Health and Safety Code requires research and monitoring of atmospheric acidity.

Chapter 10 (40910 - 40930): Chapter 10 of Part 3 of the Health and Safety Code delineates the requirements for district plans to attain the state ambient air quality standards. This chapter has sections that require plans for accounting for transported air pollutants and descriptions of the required plans (including dates and times.) Ozone and carbon monoxide nonattainment area are classified as to

Table 102.1 Ozone Nonattainment Area Classifications

| Classification | Ozone Concentrations |
|----------------|-------------------------------------|
| Moderate | >0.09 ppm to not more than 0.12 ppm |
| Serious | 0.13 to 0.15 ppm (inclusive) |
| Severe | 0.16 to 0.20 ppm (inclusive) |
| Extreme | >0.20 ppm |

Table 102.2 Carbon Monoxide Nonattainment Area Classifications

| Classification | Carbon Monoxide Concentrations |
|----------------|----------------------------------|
| Moderate | >9.0 ppm to 12.7 ppm (inclusive) |
| Serious | >12.7 ppm |

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the severity of the nonattainment conditions (Tables 102.1 and 102.2.) In Chapter 10, increasingly more restrictive requirements are set out for more severe nonattainment conditions. In addition, Section 40930 of the chapter requires that the districts submit an annual report to the ARB identifying the days which the standards were violated.

103 SAFETY CONSIDERATIONS

Safety must always be considered when operating an air monitoring station. The Air Resources Board offers a health and safety course and technical manual. A station operator should seriously consider taking the ARB health and safety class, or some similar class.

The most common hazard associated with monitoring stations is that of height. Probe inlets, samplers, and meteorological instruments must usually be elevated at least several meters above ground level. Often the inlets and samplers are located on roofs and to service them the operator must climb a ladder. Also, the meteorological instruments are usually placed at various levels on a tower. Servicing the meteorological instruments is usually by ladder or by lowering the tower.

Another significant safety issue associated with ambient air monitoring is the compressed gases used for calibrations and daily spans of the instruments. The cylinders are inherently hazardous due to their high pressure. In addition, the gases used may be toxic (CO, H₂S, etc.) or may be hazardous since the gases could displace the breathable oxygen in a room (e.g. N₂.)

104 ON LINE AIR POLLUTION DATA SOURCES

The advent of the Internet has introduced a new means of accessing air quality data. In the past data was available primarily via hard copy reports. Persons who needed a larger data set (e.g. for trend analysis or scientific research) could get a disc copy of the data from the state or other agency archiving the data. The U.S.EPA's AIRS database has long been the national archives (although for research purposes the AIRS database is sometimes insufficient.) Today, many states and districts access and download the data from their monitoring stations via Internet service. In many cases, the agency allows the general public to also access the data via those lines. A major caveat with data available in this man-

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ner is that the real-time data have not been subject to QC/QA analysis and so may contain errors; this data must be used with extreme care.

Access to the California Air Resources Board's air quality database is available at: <http://www.arb.ca.gov/aqd/aqd.htm>. The data is also available on CD ROM. The U.S.EPA maintains an Internet web site (<http://www.epa.gov/airnow/statedata.htm>) linking to the states with real time data available. Currently, there are 17 states linked in this manner. In addition, air quality data from around the world is available through Internet links. For example: Victoria Australia (<http://www.epa.vic.gov.au>), Brazil (<http://www.cetesb.br/cet0601.htm>), and Mexico City (<http://www.calidad-del-aire.gob.mx/sima/ddf/indice.html>) are directly linked on the U.S.EPA web page; England (<http://www.aeat.co.uk/netcen/aqarchive/auto.html>) and Germany (<http://www.uis-extern.um.bwl.de/lfu/abt3/luftdat.htm>) are also readily available.

105 REFERENCES

1. Goddard Space Flight Center, National Aeronautics and Space Administration, *Atmospheric Chemistry Data and Resources - Historical Atmosphere*, http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/ATM_CHEM/historical_atmosphere.html.
2. Roscoe, H.K., and Clemitshaw, K.C., (1997), Measurement Techniques in Gas-Phase Tropospheric Chemistry: A Selective View of the Past, Present, and Future, *Science*, **276**, 1065-1072.
3. Anfossi, D. and Sandroni, S., (1997), Short Communication - Ozone Levels in Paris One Century Ago, *Atmos. Environ.*, **31**, 3481-3482.
4. Goklany, I.M., (1998) Did Federalization Halt a Race to the Bottom for Air Quality, *EM*, June, 1998.
5. Pasquill, F., and F.B. Smith, 1983, *Atmospheric Diffusion, Third Edition*, Ellis Horwood Limited, Chichester.
6. *Code of Federal Regulations, Title 40, Part 50*, 1998, U.S. Government Printing Office.
7. *Code of Federal Regulations, Title 40, Part 53*, 1998, U.S. Government Printing Office.

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8. *Code of Federal Regulations, Title 40, Part 58*, 1998, U.S. Government Printing Office.
9. *Code of Federal Regulations, Title 40, Part 51*, 1998, U.S. Government Printing Office.
10. *California Health and Safety Code, California Air Pollution Control Laws*, 1998 Edition.

In order to understand ambient air monitoring and to design a cogent ambient surveillance network, a fundamental knowledge of pollutant properties, sources, sinks, transport modes, and effects is needed. The goal of this chapter is to give such a background to air pollutants and their monitoring.

201 THE AIR AND THE ATMOSPHERE

To discuss air pollution, we first need to discuss what is air. Air is a mixture of gases consisting primarily of nitrogen and oxygen essential for life. The average person breathes approximately 16 kilograms of air each day.¹

201.1 PROFILE OF THE ATMOSPHERE

Compared to the 6371 km (3959 mile) radius of the earth,² the atmosphere is an extremely thin and tenuous layer surrounding the earth and its life. There is no absolute upper edge to the atmosphere, even spacecraft and satellites are significantly affected by atmospheric drag.

Although the atmosphere can still support air breathing aircraft engines, as a mixture of gases capable of supporting life, the practical upper limit to the atmosphere is around 5000 meters (16,400 ft) above sea level.³ Persons venturing above this level need supplemental oxygen to breathe. This represents a layer only 0.078% of the radius of the earth. On a scale from San Francisco to New York City as the radius of the earth, the thickness of the breathable atmosphere would not cross the San Francisco Bay.

The atmosphere is divided into four distinct layers: troposphere, stratosphere, mesosphere, and thermosphere with boundary layers (tropopause, stratopause, and mesopause) between each (Figure 201.1). The troposphere, or lower 11 km of the atmosphere is most important for air pollution purposes, although a lot of news has been devoted to the issue of depletion of ozone in the stratosphere by chlorofluorocarbon compounds.

Up to an altitude of about 90 km the composition and molecular weight remain fairly constant.^{2,3} Above 90 km the molecular weight decreases rapidly as the composition changes as the atmospheric gases diffuse into space. In the lower atmosphere the air is made up of nitrogen and oxygen along with miscellaneous trace gases (Table 201.1). The pollutant gases, while typically at trace concentrations, can have significant health, welfare, and ecological impacts.

200 FUNDAMENTALS OF AIR MONITORING

201.2 AIR BASINS

Air basins are regions of similar meteorological and geographic conditions for which a cogent plan of monitoring and emission control can be devised. Air basin boundaries are usually drawn with consideration of political boundaries, when practicable. Some states may require only a single air basin, or in cases, such as California, the states may be highly dissected into smaller air basins. Other than the need to draw basin boundaries for political and planning reasons, in some parts of the country air basins may cover several states. Rarely will state boundaries coincide with the ideal air basin boundaries. This highlights the need for interstate (and international) cooperation in air monitoring and air pollution control.

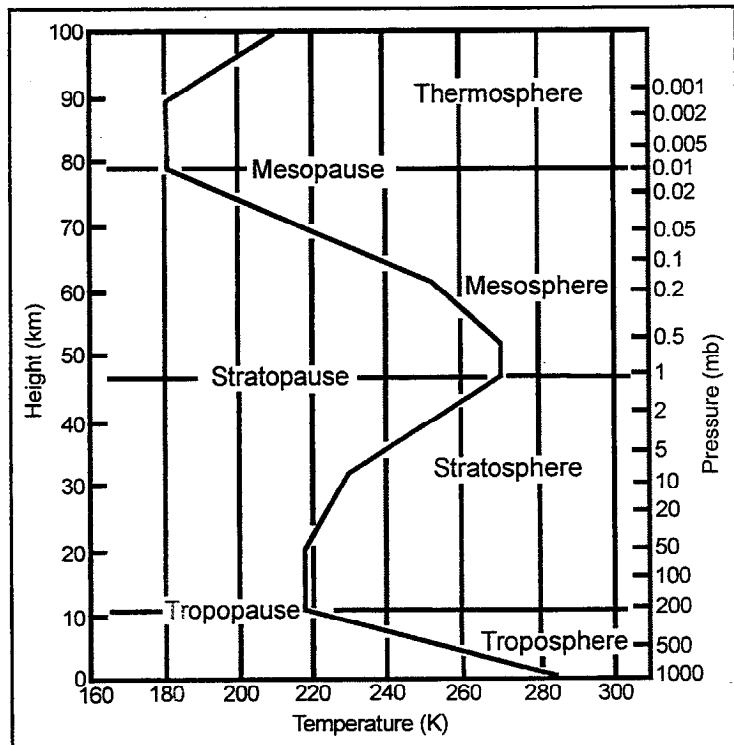


Figure 201.1 Temperature vs. Altitude Profile in the Atmosphere³

Table 201.1 Gaseous Composition of the Atmosphere^{2,3}

| Component Gas | % | Component Gas | ppm |
|-----------------|----------------|------------------|---------------|
| N ₂ | 78.084 ± 0.004 | Ne | 18.18 ± 0.04 |
| O ₂ | 20.946 ± 0.002 | He | 5.24 ± 0.004 |
| Ar | 0.934 ± 0.001 | CH ₄ | 2 |
| CO ₂ | 0.033 ± 0.001 | Kr | 1.14 ± 0.01 |
| | | H ₂ | 0.5 |
| | | N ₂ O | 0.5 ± 0.1 |
| | | Xe | 0.087 ± 0.001 |

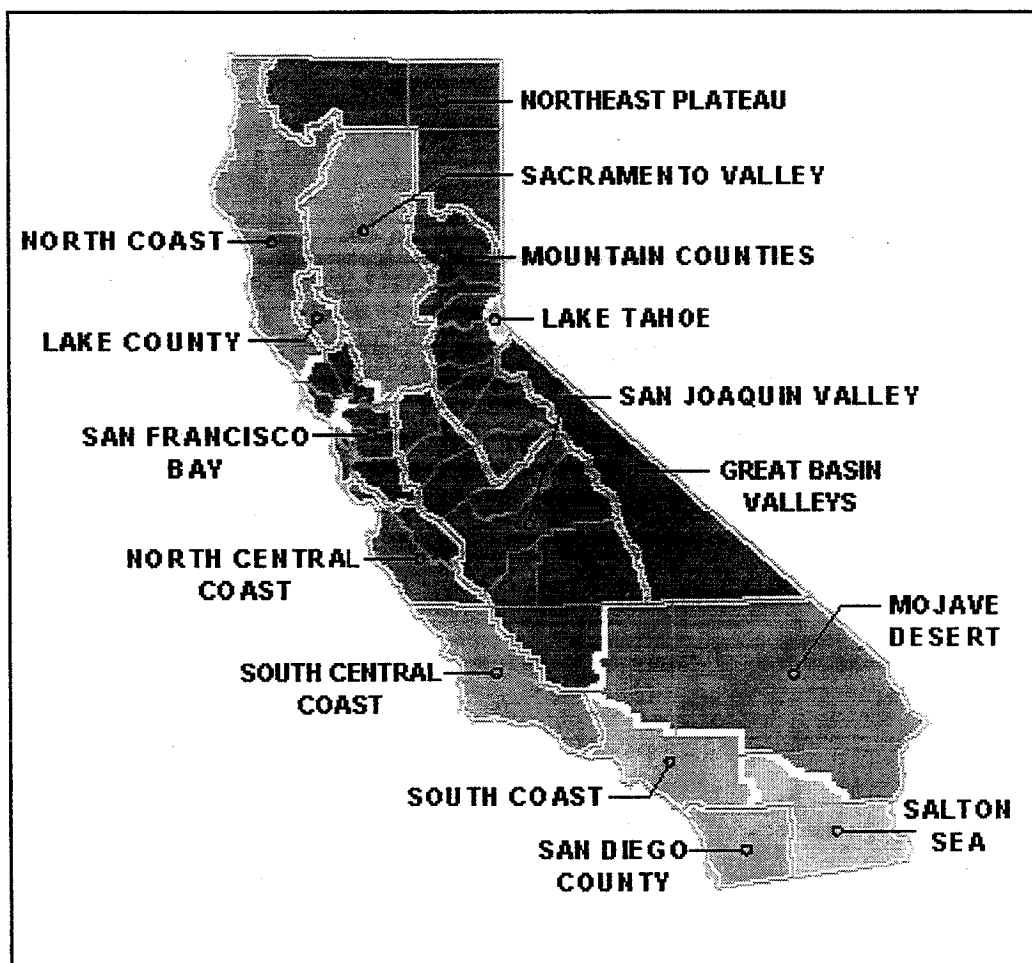


Figure 201.2 California Air Basins

201.2.1 California Air Basins

The state of California is divided into 15 air basins (Figure 201.2). The Lake Tahoe air basin is notable since the ambient air quality standards for CO and visibility reducing particles are different in this basin. The CO standard is lower since, at the high elevation of this basin, the partial pressure of oxygen is lower than at lower elevations. This means that the health effects of CO become manifest at lower concentrations. The visibility reducing particle standard is lower to protect the scenic beauty of the Lake Tahoe vistas, a prime economic asset of the area.

200 FUNDAMENTALS OF AIR MONITORING

**Table 202.1 Density of Air and Pollutants (kg/m³
at 0°C, 1.0132 bar, except # at 100°C)**2,4**

| Component | Density | Component | Density |
|-------------------|---------|--------------------|---------|
| Air* | 1.293 | CO* | 1.25 |
| Nitrogen* | 1.25 | SO ₂ * | 2.927 |
| Oxygen* | 1.43 | H ₂ S* | 1.54 |
| CO ₂ * | 1.97 | Ozone* | 2.14 |
| Water Vapor* | 0.77# | Methane* | 0.72 |
| | | NO** | 1.34 |
| | | NO ₂ ** | 1.45 |
| | | N ₂ O** | 1.98 |

202 AMBIENT AIR POLLUTANTS

The air we breathe is contaminated with nearly 200 million tons of pollutant emissions each year.⁵ Pollution is created by different sources, but 90% is anthropogenic. The remainder are primarily biogenic in origin, for example: organic compounds from pine trees. In California, a large percentage of the air pollutants are automotive related, followed by industry, power plants, and consumer products. The pollutants in the atmosphere can be categorized as criteria pollutants (as defined by the U.S. EPA) or non-criteria pollutants. An additional differentiation of pollutants is into primary and secondary pollutants. The non-criteria pollutants are compounds emitted into the air that may be of significant air quality importance, but were not included by the U.S. EPA as a criteria pollutant. Primary pollutants are those that are emitted in the form monitored; whereas secondary pollutants are those that are not emitted by any source, rather they are formed through atmospheric chemistry.

Primary and secondary ambient air quality standards have been set for most pollutants (see Chapter 300 of this manual). The primary standards define air quality levels which protect the public health with an adequate margin of safety. Secondary standards protect the public welfare.

200 FUNDAMENTALS OF AIR MONITORING

Ambient Air Monitoring

202.1 CRITERIA POLLUTANTS

The U.S. EPA has designated six criteria pollutants as the principle indicators of air quality. National Ambient Air Quality Standards (NAAQS) have been established for each of the criteria pollutants. Primary standards are set at a level which is judged to protect the public health. The secondary standards are set at a level that is judged to protect public welfare, i.e. to protect property and prevent environmental damage. The criteria pollutants are: sulfur oxides (sulfur dioxide), particulate matter, carbon monoxide, ozone, nitrogen dioxide, and lead. California has established ambient air quality standards that are more protective than the national standards.

In the following sections the description, sources, chemistry of formation and reactions, health effects, biological (other than health) effects, and materials effects of the criteria pollutants will be discussed. Except as noted, this information was obtained through the U.S. EPA Office of Air Quality Planning and Standards (OAQPS). The specific levels of the pollutant standards will be discussed in Chapter 300 later in this manual.

202.1.1 Sulfur Oxides (SO₂)

Description

Sulfur dioxide is the most common oxide state of sulfur pollutants and the state for which the standard has been written. It is a colorless, pungent, nonflammable gas emitted into the atmosphere mainly through the combustion of sulfur-containing fossil fuels.

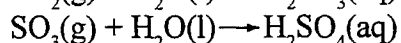
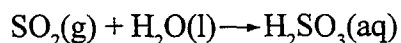
Sources

Sulfur dioxide is primarily emitted from combustion of fossil fuels containing sulfur and the reduction of metal ores. In the United States, more than half the SO₂ pollution originates from fossil fuel fired power generating plants. To a much lesser extent SO₂ can be the result of the oxidation of sulfur compounds from microbial activity and sulfur from sea-spray. Episodically, extremely high SO₂ concentrations can be the result of volcanic eruptions.

Chemistry of Formation and Reactions

When SO₂ is emitted into the ambient air it often oxidizes forming sulfur trioxide which rapidly combines with water vapor to form sulfuric acid. The sulfuric acid may return to the earth in the form of acid rain, snow, or fog. It may also further react to form sulfates which form fine particulate matter. In many areas

the majority of the fine particulate mass is sulfate. The oxidation of SO_2 may occur in the gaseous phase where the sulfuric acid itself may condense to form condensation nuclei or in the aqueous phase as the SO_2 is adsorbed into droplets (e.g., clouds). Since sulfate particles tend to be hygroscopic, they may grow rapidly by the adsorption of water.



Health Effects

Sulfur dioxide's main effect upon human health is irritation of the upper respiratory tract. Exposure to SO_2 can cause impairment of respiratory function, aggravation of existing respiratory disease (especially bronchitis and asthma), and a decrease in the ability of the lungs to clear foreign particles. Inhaling SO_2 constricts the bronchia causing breathing difficulty and increased pulse and respiratory rates. It can also lead to increased mortality, especially if elevated levels of particulate matter are also present. For 2 - 3 weeks after exposure to elevated particulate matter, significant harm (i.e. serious and widespread health effects occur to the general public) occurs with exposure to 1.0 ppm of SO_2 . Exposure to concentrations as low as 8 ppm can produce coughing in fit individuals.

Biological Effects

The natural and built environments are also subject to SO_2 damage. High levels of SO_2 can harm the leaves of certain vegetables; spinach and lettuce for example, are sensitive to SO_2 exposure.

Material Effects

SO_2 is a precursor to sulfates, which are associated with acidification of lakes and streams, accelerated corrosion of buildings and monuments, and reduced visibility.

202.1.2 Particulate Matter

The atmospheric aerosol, that is, the particles that are found in the troposphere, is a complex and dynamic mixture of solid and liquid particles from natural and anthropogenic sources. Particulate matter is a "grab-bag" of almost all pollutants emitted into the atmosphere (Figure 202.2). Atmospheric aerosol plays an important role in climate and atmospheric chemistry in addition to health and welfare effects. Particles scatter sunlight, provide condensation nuclei for cloud droplets, and participate in heterogeneous chemical reactions.⁶ There is a complex

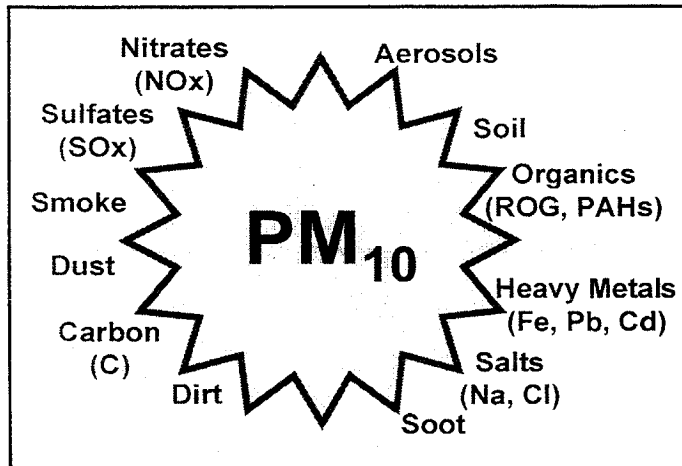


Figure 202.2 Composition of Particulate Matter

interrelationship between OH, NO₃, O₃, polycyclic aromatic hydrocarbons, and fine particulate.⁷

Description

Particulate matter is made up of very small fragments of material ranging in size from submicrometer to visible. Particle sizes typically range from 0.001 to over 100 μm .

As points of reference, an air molecule has a diameter of about 0.00037 μm and a human hair is approximately 70 μm in diameter. Particulate matter is referred to by a number of terms in common usage:⁸

- Aerosol: A suspension of solid or liquid particles in a gas. Aerosols are usually stable for at least a few seconds and in some cases may last a year or more. The term aerosol includes both the particles and the suspending gas (usually air.)
- Dust: A solid-particle aerosol formed by mechanical disintegration of the parent material, such as by grinding and crushing.
- Course particles: Particles larger than 2.5 μm .
- Fine particles: Particles less than 2.5 μm .
- Fume: A solid-particle aerosol produced by the condensation of vapors or gaseous combustion products. Particle size is usually less than 1.0 μm .
- Smoke: A visible aerosol resulting from incomplete combustion. Particles may be solid or liquid and have a diameter approximately the size of a wavelength of light (0.4 - 0.7 μm .)
- Mist: A liquid-particle aerosol formed by condensation or atomization. Particles may range from submicrometer to about 20 μm .
- Fog: A visible mist.
- Smog: Particles consisting of photochemical reaction products, usually combined with water vapor. Particles are usually less than 1 or 2 μm .
- Cloud: A visible aerosol with defined boundaries.

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Particulate matter is usually characterized by its size (diameter.) Most samplers collect and separate particulate matter based on particle inertia which is related to the particle's size, geometry, and density. Figure 202.1 illustrates how particles with different physical size, geometry, and density (ρ) all have the same settling velocity. The design of particulate samplers is based on the aerodynamic diameter of the particles. The aerodynamic diameter standardizes for both shape and density. A particle with an aerodynamic diameter of $1\text{ }\mu\text{m}$ behaves, in an aerodynamic sense, like a $1\text{ }\mu\text{m}$ water droplet regardless of its shape, density, or physical size. It is indistinguishable from other particles of different physical size, shape, and density with an aerodynamic diameter of $1\text{ }\mu\text{m}$.

Particulate matter ambient monitoring programs have progressively emphasized smaller and smaller particles. For most

particulate monitoring by the EPA and state regulatory agencies through the early 1980's, total suspended particulate (TSP) samples were collected. TSP is defined as particulate matter with a nominal maximum diameter of $40\text{ }\mu\text{m}$. The reference method for determining TSP state that the sampler flow rate and shelter geometry must favor the collection of particles up to $25 - 50\text{ }\mu\text{m}$ aerodynamic diameter, depending on wind speed and direction.

In 1987 the particulate NAAQS was revised to implement size-selective particle sampling designed with a $10\text{ }\mu\text{m}$ cut point (PM_{10} , $d_{50} = 10\text{ }\mu\text{m}$). The PM_{10} samples concentrate on particles with more specific health effects than TSP. Particles larger than PM_{10} are largely excluded by the nose and larynx and do not penetrate into the lungs where the principle health effects occur.

In 1996 a further reduction in the NAAQS particle size was proposed. The revised particulate NAAQS, which became effective in September 1997, added a

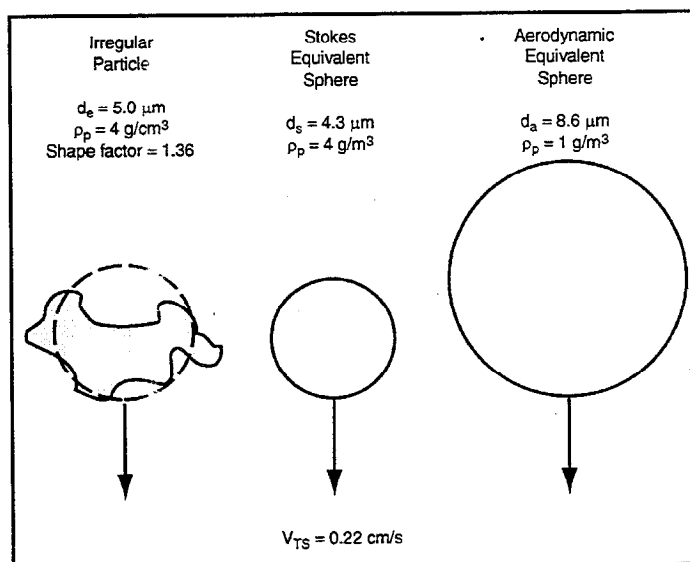


Figure 202.1 Equivalent Particle Sizes

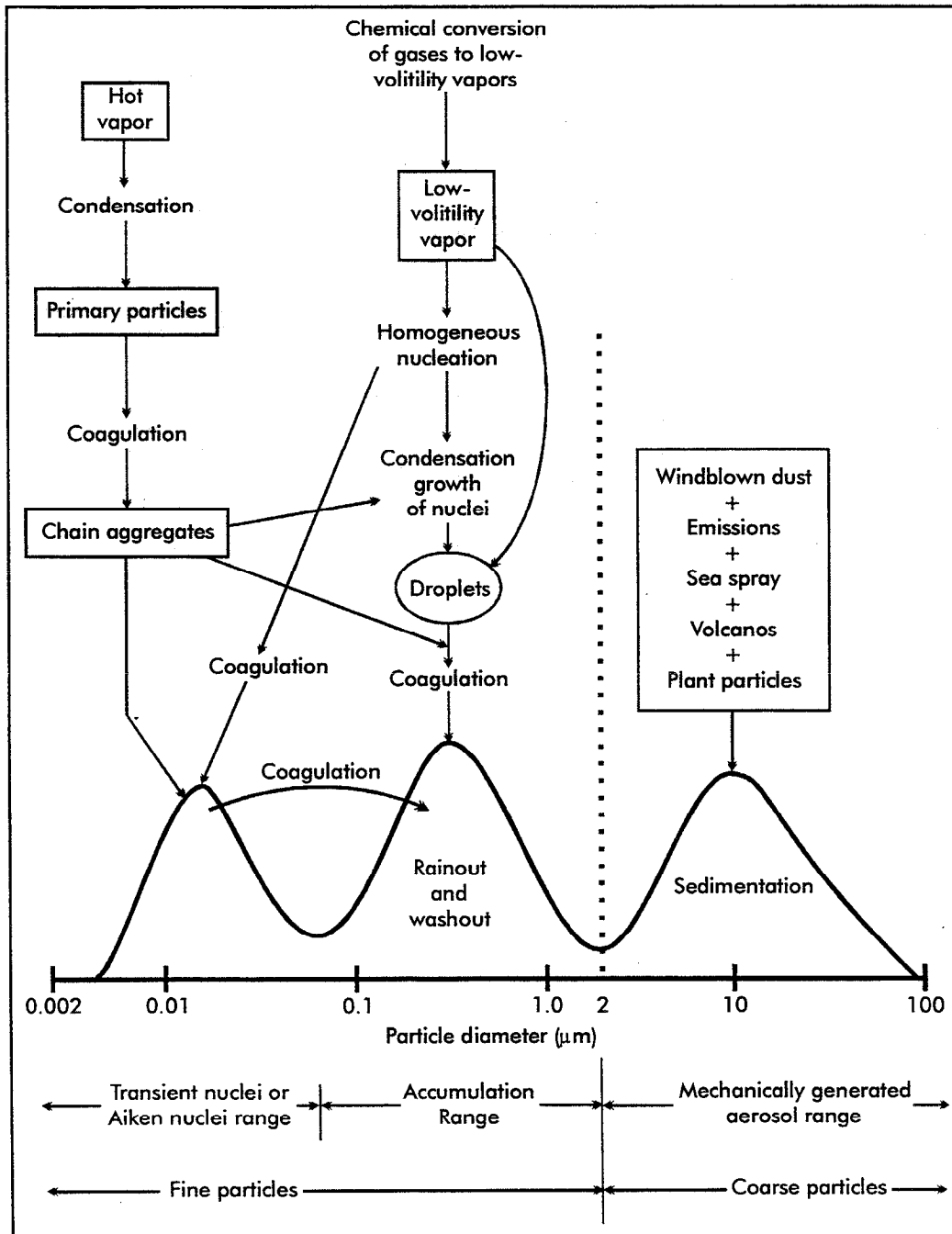


Figure 202.2 Size Distribution, Formation, and Removal

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Table 202.2 Sources of Global Particulate Emissions (Particles Less Than 20 μm)⁸

| Source | Amount (10 ⁶ metric tons/yr) |
|---|--|
| Natural | |
| Soil dust | 100-500 |
| Forest fires | 3-150 |
| Volcanoes | 25-150 |
| Sea-salt | 4-300 |
| Gas-to-particle conversion | 270-900 |
| Photochemical (from plant hydrocarbons) | 75-200 |
| Total for natural sources | 480-2200 |
| Man-made | |
| Direct emissions | 10-90 |
| Gas-to-particle conversion | 160-240 |
| Photochemical | 15-90 |
| Total for man-made | 185-420 |

new 24 hour and annual average standard for $\text{PM}_{2.5}$ particulate matter. The PM_{10} standards were retained; however, the compliance determination method was changed. The 1997 $\text{PM}_{2.5}$ and revised PM_{10} standards were challenged in court and, on 14 May 1999 the U.S. Court of Appeals for the District of Columbia Circuit remanded to the EPA the $\text{PM}_{2.5}$ standards and vacated the revised PM_{10} standard. Unless and until the Supreme Court overturns this decision, the old PM_{10} standard remains in effect.

The fine ($\text{PM}_{2.5}$) particle fraction often has a very different chemical composition than the coarser fraction ($\text{PM}_{2.5}$ - PM_{10}) and have the ability to penetrate into deeper and more sensitive parts of the lung. Therefore, the $\text{PM}_{2.5}$ NAAQS concentrates on the most critical particles with respect to health effects of particulate matter. Although the coarse fraction particles can also have significant health effects. The coarse and fine fraction particles can be treated as essentially distinct pollutants.

Sources

The majority of particulate mass in the atmosphere, both natural and anthropogenic, is secondary formed in the atmosphere from gaseous emissions (Table 202.2).⁸ On a global scale, natural sources far exceed the anthropogenic sources; however, the natural sources are widely distributed around the globe and most of their mass contribution comes from area sources. Man-made sources, on the other hand, are concentrated in industrialized areas. The industrialized areas are also where the human population (i.e. the targets of health effects concerns) is

concentrated. Most of the particulate mass is in the lower 1 - 2 km of the atmosphere, where people live.

A direct comparison between the natural and anthropogenic particulate matter sources can be misleading; the majority of the soil dust, volcanic emissions, and anthropogenic direct emissions are large particles that deposit near the source. On the other hand, fires and secondary sources (i.e. gas-to-particle conversions) produce fine particles that remain suspended in the atmosphere for an extended time and may travel global scale distances.

Since a major fraction of the ambient particulate matter arises from atmospheric gas-to-particle conversion, it is coupled to the chemistry of the atmosphere. Attempts to reduce particulate matter levels require control of the emission of the gaseous precursors. Therefore, controlling SO₂ emissions and controlling the same hydrocarbon and nitrogen oxide emissions that will reduce ozone levels will also reduce particulate matter.

Chemistry of Formation and Reactions

Coarse particulate matter is most commonly generated by mechanical abrasion, grinding and fracturing. Fine particles are, however, most commonly generated in combustion sources and by gas-to-particle condensation and coagulation of submicrometer nuclei.

An industrial facility, such as a power plant may produce coarse fly ash particles and fine condensed fly ash particles with in the firebox of the boiler and second-

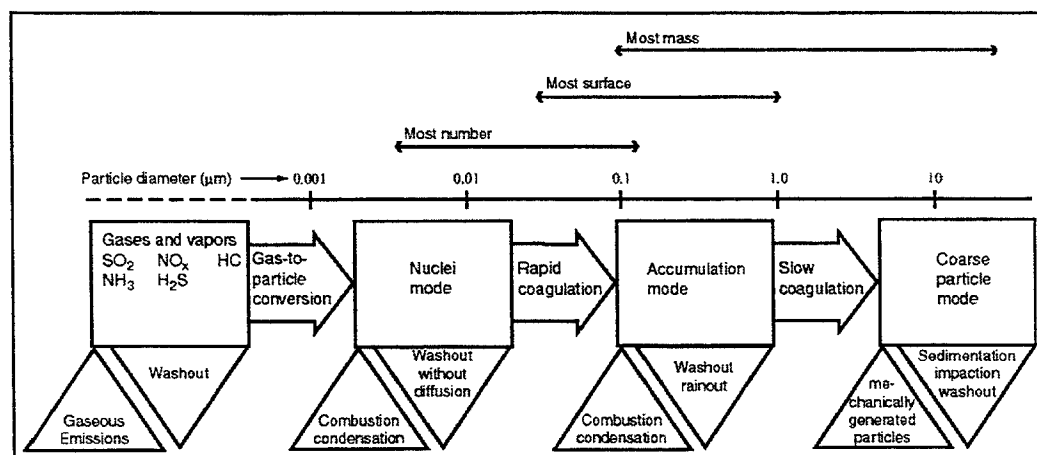


Figure 202.3 Process That modify Urban Atmospheric Aerosols⁸

ary particulate matter outside the plant as the plume from the stack disperses, ages, and reacts in the atmosphere.

Once emitted or formed in the atmosphere, particles can grow by condensing additional material onto their surface and by coagulation with other particles (Figures 202.2 and 202.3). Particles are removed from the atmosphere after they grow to micrometer or larger size by settling or impaction on surfaces. Very small particles (less than $0.1 \mu\text{m}$) diffuse readily to surfaces and other particles and so are removed from the atmosphere. Large particles (larger than $20 \mu\text{m}$) are removed from the atmosphere by sedimentation within hours. In addition to adsorbing and absorbing gases, particles can coagulate together to form larger particles from smaller ones.

Finally, innumerable chemical reactions can occur on the surface of particles and in the condensed water of the particle. The chemistry of particulate matter is immensely complex and beyond the scope of this manual. Many books, reports, and scientific journal publications about particulate chemistry exist. Anyone wishing additional information is encouraged to pursue those avenues.

Health Effects

The hazard caused by particulate matter depends partly on the physical mass of material deposited in the lungs, but, more importantly, on the chemical composition of the particles and the site in the respiratory system at which they lodge (Figure 202.4). Large

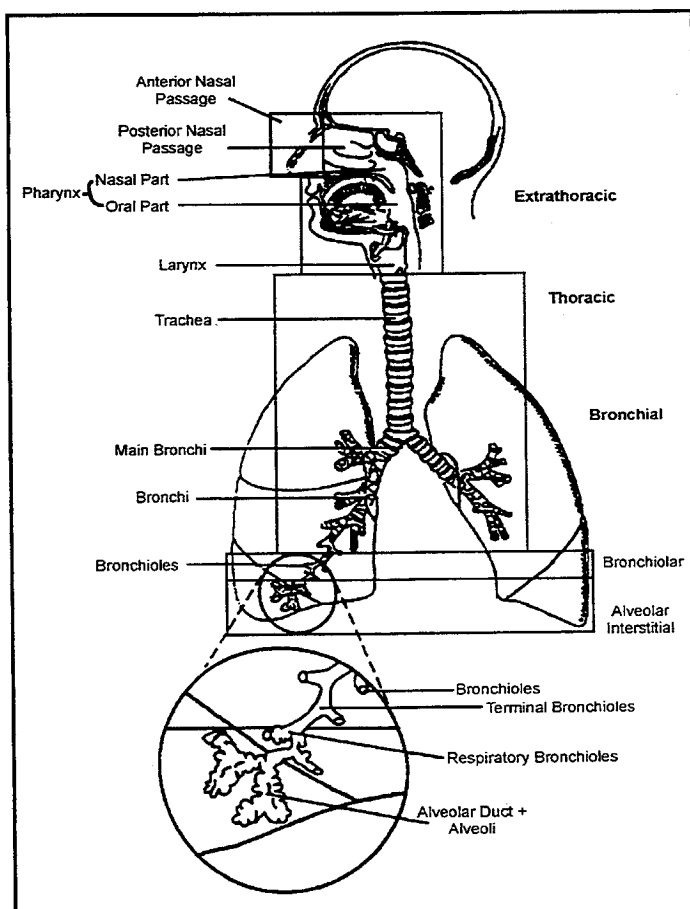


Figure 202.4 The Respiratory System

particles are removed in the nose and pharynx while small particles penetrate into the depths of the lungs where the body has fewer defenses.

Once deposited, particles are retained in the lung for varying times depending on their chemical properties, location in the lung, and the clearance mechanism of the lung in that region. Because of the gas exchange properties of the deep lung regions, these regions do not have the mucus layer or ciliary clearance mechanisms that remove particles from the lung in the larger passages. Because of this, insoluble particles are cleared very slowly over the period of several months. Soluble particles may dissolve and pass through the alveolar membrane into the bloodstream.

Biological Effects

Biological effects of particulate matter are primarily related to the composition of the particles. The composition of the particle will depend on the source and history (i.e. what materials have condensed onto the particle) of the particles. For example, the particles may be highly acidic if they contain significant quantities of un-neutralized sulfate or nitrate. Diesel exhaust particles often contain high levels of adsorbed hydrocarbons.

Most plants are fairly resistant to particulate pollution. The particles, except in rare instances, cannot penetrate the leaf cuticular surface. With heavy particulate exposure, however, the cuticle may be eroded away, especially if the particles are highly acidic. Particles that contain high levels of nitrate, ammonium, or sulfate can indirectly affect the plants through fertilization and other chemical reactions in the soil. While fertilization sounds like a beneficial effect, it can be highly detrimental to a plant's life cycle and ecosystem-wide relationships. Acidification of the soil, streams, and lakes has been shown to change the available nutrient concentrations and to release heavy metals, which can be toxic to plants and animals.

Material Effects

The most obvious material effect of particulate matter is soiling. In addition there are many other effects, principally based on the composition of the particles. The acidity of the particles can lead to corrosion of stone and metal used in buildings, statuary, etc.

Another physical effect, related to the biological effects, is the acidification of soils, streams, and lakes. By changing the pH (and other composition) of the

lithosphere and hydrosphere, the chemistry of the soils and water bodies can be changed, as can the weathering of soils and rocks.

Fine particulate matter is also the primary causes of haze and visibility impairment. In the eastern U.S. the visibility range is commonly 14-24 miles vs. a natural range of 90 miles. In the west, the visibility is reduced from about 140 miles to about 33-90 miles. The natural visibility range is greater in the west because the climate is much drier, i.e. lower relative humidity. It has been demonstrated that the persistent haze in the Grand Canyon is due, in large part, to fine particulate from a nearby coal fired power plant. Transported particulate matter from the Los Angeles area also degrades the visibility in the Grand Canyon. Twenty percent of the visibility problems in the Rocky Mountain National Park has been attributed to Los Angeles generated particulates.⁹

202.1.3 Carbon Monoxide

Description

Carbon monoxide (CO) is an odorous, colorless, and poisonous gas.

Sources

The vast majority of carbon monoxide is produced by the incomplete combustion of carbon in fuels. The largest source (approximately 81%¹⁰) of CO emissions is motor vehicles. Thus, the focus of much of the CO monitoring has been on traffic oriented (often microscale) sites in urban areas. Other major CO sources are woodburning stoves, incinerators, and industrial sources. A small natural background of CO (approximately 0.15 ppm¹¹) is produced by microbial action. Carbon monoxide is also produced by the chemical oxidation of methane and other hydrocarbons and organic compounds by hydroxyl radicals.

Carbon monoxide has been observed to be transported for great distances. On March 29, 1997 elevated CO levels were observed at Cheeka Peak, on the westernmost point of Washington state's Olympic Peninsula. These elevated concentrations were traced to Asia, although the source cannot yet be ascribed to coal burning in China or oil burning in Tokyo.

Chemistry of Formation and Reactions

The principle atmospheric reaction mechanism is via oxidation by hydroxyl radicals.¹³ The primary sink of CO is via reactions and biological sinks in the soil.¹⁴

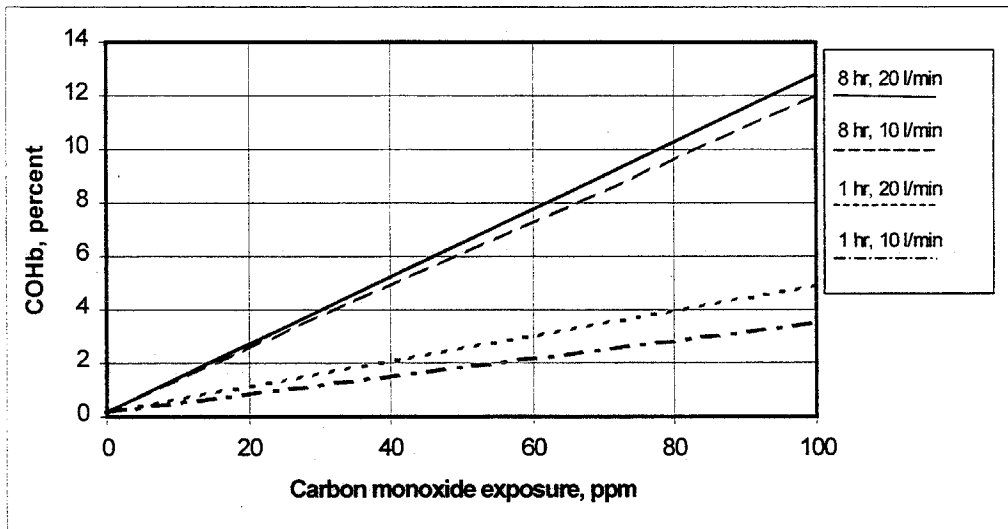


Figure 202.5 Relationship Between Carbon Monoxide Exposure and Carboxyhemoglobin (COHb) Levels (1 hour or 8 hour exposure, at rest [10 liters per minute breathing] or light exercise [20 liters per minute breathing])

Emissions of NO_x , VOC, and CO are considered precursors for ozone formation. The reaction of CO with OH is important for a number of reasons: The reaction is the primary means of destruction of CO in the atmosphere. It also is one of the primary means of removing OH. Finally, the reaction of CO with OH forms

Table 202.3 Physiological Effects With Increasing Levels of Carboxyhemoglobin

| COHb level, percent | Demonstrated Effects |
|---------------------|--|
| Less than 1.0 | No apparent effect. |
| 1.0 - 2.0 | Some evidence of effect on behavioral performance. |
| 2.0 - 5.0 | Central nervous system effects. Impairment of time interval discrimination, visual acuity, brightness discrimination, and certain other psychomotor functions. |
| Greater than 5.0 | Cardiac and pulmonary functional changes. |
| 10.0 - 80.0 | Headaches, fatigue, drowsiness, coma, respiratory failure, death. |

HO_2 which will react with NO to generate NO_2 , important for the formation of ozone.

Health Effects

The health threat of CO is the primary concern about CO as a pollutant.

The primary health threat is from the competition of CO with oxygen for binding sites on hemoglobin molecules in the blood. Oxygen must bind loosely and reversibly to hemoglobin so as to be released to cells throughout the body. Carbon monoxide forms a more stable complex with hemoglobin (called carboxy hemoglobin) than oxygen. The stability of carboxyhemoglobin precludes the uptake of oxygen by the blood, starving the body of oxygen. The stability also means that the concentration of carboxyhemoglobin will increase with time and level of CO exposure (Figure 202.5¹⁵).

Symptoms of CO exposure (Table 202.3¹⁶) include impairment of visual perception, manual dexterity, learning ability, and performance of complex tasks, and headaches. Persons with cardiovascular and pulmonary diseases are most at risk, particularly those with angina and peripheral vascular disease. Chronic exposure to low CO levels impairs judgement and increases the time required to make decisions. At high enough levels, exposure to CO can be fatal. Due to the oxygen starvation properties, CO can also cause teratogenic effects.

Biological Effects

Plants are minimally effected by CO. At a level of about 500 ppm some effects have been observed. It is believed that at that level CO effects the photosynthetic pathway. Insects appear to be effected by about 50 ppm. At that level they become lethargic, similar to the disorientation and impairment observed in humans at about 5 ppm.

Material Effects

Carbon monoxide does not appear to directly adversely affect materials. Indirect effects may arise due to interaction in the ozone cycle and with hydroxyl radical.

202.1.4 Ozone

Depending on where ozone resides, it can protect or harm life on Earth. When it is close to the surface, in the air we breathe, ozone is a harmful pollutant that causes damage to lung tissues, plants, and materials. It also reacts with other

pollutants to form other harmful secondary pollutants such as aldehydes, ketones, and peroxyacyl nitrates.

Ozone is the most insidious and ubiquitous air pollutant affecting human health and welfare and ecological systems in the United States. Ozone pollution, precursors of which largely originate in urban areas, can extend for hundreds of kilometers downwind into rural agricultural and forested areas. California, due to its mountain/valley topography and plentiful sunshine, is especially prone to ozone formation. Episodes of elevated ozone concentrations are associated with sunny, warm, slow moving high pressure systems.

Photochemical oxidants (preliminarily ozone) are the most significant cause of agricultural loss in the United States. Ozone alone, or in combination with SO_2 and NO_2 , accounts for 90% of the annual crop losses in the U.S.¹⁷

Description

Ozone was first discovered by the German scientist Christian Friedeich Schonbein in 1839. It is a pale blue unstable gas made up of three oxygen atoms. Ozone is approximately 2.5 times as dense as regular diatomic oxygen (O_2). At -112°C it condenses into a deep blue liquid. It is a powerful oxidizing agent and, as a concentrated gas or liquid, is highly explosive.¹⁷

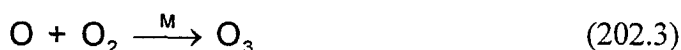
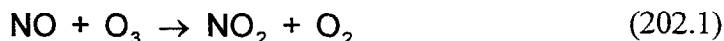
Sources

The predominant source of ozone is the atmospheric reaction of nitrogen oxides, organic matter, and sunlight. On occasion, intrusions of stratospheric ozone into the troposphere have been recorded, especially at high elevation locations such as Lake Tahoe and Mammoth Mountain in California. Indoors and in the vicinity of electric power plants, electrical discharge may contribute to the ozone concentration.

Chemistry of Formation and Reactions

Ozone is formed in the troposphere¹⁸ when monatomic oxygen atoms, which are highly reactive, combine with diatomic oxygen molecules. Availability of oxygen atoms in the atmosphere is the key to ozone formation. Under most circumstances, oxygen atoms are created by photochemical reactions of nitrogen oxides (NO_x). Most combustion sources emit preliminarily NO , which can be oxidized in the atmosphere to form NO_2 . This reaction kicks off a photochemical chain reaction in which ultraviolet light dissociates NO_2 into NO and an unstable oxygen atom that quickly combines with an oxygen molecule to form ozone.

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The three reactions show that one ozone molecule is consumed during NO oxidation to NO₂ for every ozone molecule that is produced. The reactions can cycle back and forth. The ratios of NO, NO₂, and O₃ will vary with the overall NO_x concentration and amount of sunlight, but with no net gain in ozone.

If these reactions were the only mechanisms by which ozone was formed, photochemical smog would be relatively easy to control. However, other chemicals in the atmosphere participate in the photochemical reactions, mostly by restoring the NO₂ molecule without consuming an ozone molecule, i.e short-circuiting reaction 202.1. For example, this happens when a peroxy radical (RO₂, where R represents a hydrocarbon group) derived from atmospheric oxidation of hydrocarbon emissions (VOCs and ROGs, see section 202.2.1) replaces ozone in reaction 202.1 (reaction 202.4).



In this case, an ozone molecule is produced as a result of reactions 202.2, 202.3, and 202.4. The oxidized hydrocarbon radical (RO₂) is regenerated by reaction of

the reduced hydrocarbon radical (RO) with oxygen. A single hydrocarbon radical can, in this manner, generate many NO₂ molecules; therefore, the net ozone concentration increases rapidly. The photolytic dissociation of only a very few NO₂ molecules is needed to initiate the process.

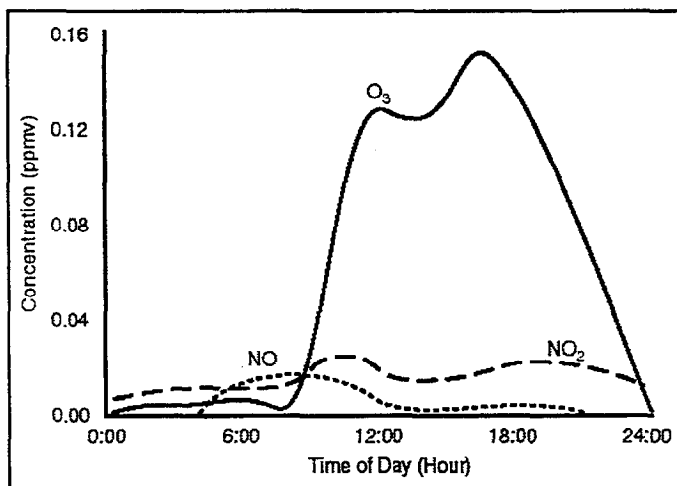


Figure 202.6 Diurnal Variations in NO, NO₂, and O₃ Concentrations¹⁷

Since reaction 202.2 requires UV radiation,

ozone production is highly dependent on sunlight and therefore time of day (Figure 202.6). Therefore, ozone concentrations are highest during the afternoon. An additional consequence of the requirement for light to drive the reactions is that after sundown ozone production stops and reactions of ozone on surfaces and other molecules depletes the atmospheric concentration of ozone. At night ozone reacts with NO_2 to create nitric acid as a sink of the NO_2 (see section 202.1.5 and 202.3.2).

Health Effects

Acute exposure to ozone can cause irritation to the nose and throat¹⁹. Ozone reaching the lungs can cause irritation of the lungs, causing coughing and/or shortness of breath. Higher level exposure can cause headache, upset stomach, vomiting, and pain or tightness in the chest. Lung exposure can also cause a build-up of fluid in the lungs (pulmonary edema) and severe shortness of breath.

Chronic effects preliminarily consist of permanent structural lung damage. Chronic exposure to ozone can also be teratogenic and possibly mutagenic.

Studies have shown an association between elevated ozone levels and increased hospital admissions.¹⁰

Ozone exposure reduces lung function and sensitizes the lungs to other irritants. Since high ozone frequently occurs during inversion episodes, which generally have high levels of other pollutants, ozone exposure can exacerbate the exposure to particulate matter, SO_2 , etc.

Biological Effects

Ozone is responsible for approximately 1 to 2 billion dollars of agricultural crop loss in the U.S. each year.¹⁰

Plants respond to long-term cumulative ozone exposures and are more sensitive than humans to ozone stress.²⁰ The observed plant responses to ozone exposure include: visible injury, loss of productivity, inability to withstand other stresses, accelerated senescence, and changes in metabolic pathways.²¹ Ozone is not stable within the plant's leaves, cells, or cell walls due to its high reactivity. Three major transformation species are believed to be formed: superoxide (O_2^-), hydrogen peroxide (H_2O_2), and hydroxyl radical (OH).

Three elements of plant biochemistry respond to ozone exposure: the constitutive chemicals in the apoplasmic fluid and cell membranes, messenger molecules

formed as a result of the reactions with the constitutive chemicals, and pathogenic RNAs and proteins formed in response to the messenger molecules.²² Ozone passing through the stomata is very quickly consumed by oxidizable substances lining the leaf internal spaces, as indicated by studies that have found that the ozone concentration within the leaf is zero. Ozonolysis of constitutive chemicals such as ethylene, isoprene, ascorbic acid, phenylpropenoids, and proteins (both soluble and membrane-bound) can quickly destroy the ozone; however, in many cases, additional reactive peroxides and radicals are produced before the ozone is completely biochemically removed.

Lesions characteristic of ozone damage occur in the cells of the palisade parenchyma.

Ethylene is one of the principle messenger molecules that rapidly responds to ozone exposure. Messenger RNA production rapidly increases after exposure to ozone, indicating the activation of plant defense and repair mechanisms.

All parts of plant cells contain proteins. They may be structural or catalytic and either free in solution or membrane-bound. Reaction of the proteins with ozone and ozonolysis produced peroxides and radicals can have devastating effects. Work done by this author²³ has shown an increase of metabolic activity consistent with protein synthesis for defense and repair.

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Ozone levels exceeding the EPA's standard have been blamed for approximately \$1 to \$2 billion of agricultural crop yield loss in the U.S. each year¹⁰. In California, significant agricultural losses occur. The losses vary by crop, but amount to 32%, 17%, and 23% for cantaloupe, cotton, and grapes, respectively¹¹. In addition, losses of ecological resources and other significant agriculturally related losses of timber, etc. occurs.

Material Effects

The material damage caused by ozone is generally related to the instability and reactivity of the ozone molecule. Rubber and some plastic parts and materials are particularly vulnerable to ozone damage.

202.1.5 Nitrogen Dioxide

Nitrogen dioxide (NO₂) belongs to a family of highly reactive gases, which are referred to in general as nitrogen oxides (NO_x). The appellation "NO_x" includes NO₂, nitric oxide (NO), nitrous oxide (N₂O), and a wide variety of other oxides.

The total reactive forms of nitrogen oxides are referred to as NO_x . Although a number of oxides may be summarized as NO_x , NO_2 and NO are the two principle oxide forms assumed. Often NO_x is calculated as the sum of NO and NO_2 . Nitric oxide is the most common form emitted into the atmosphere, with NO_2 formed through atmospheric chemistry. Together with hydrocarbons, NO_x plays an important role in the formation of ozone. It also is the primary progenitor of nitric acid deposition.

Description

Nitrogen dioxide is a brownish, highly reactive gas that is present in all urban atmospheres.²⁷ It is very soluble in water and decomposes upon going into solution. Since NO_2 reacts instantly with water to form nitric and nitrous acids, it does not exist, per se, in water.^{2,25} In contrast, NO is extremely insoluble in water (0.006 g/100 g water). What little NO dissolves in water quickly reacts in the same manner as NO_2 . Nitrogen dioxide is also known as nitrogen peroxide.

Sources

Nitrogen oxides are emitted into the atmosphere mainly as a result of combustion processes. The primary form of emission is as NO with NO_2 being formed through atmospheric chemistry. Gas turbines, common in cogeneration facilities; however, emit more NO_2 than NO . The vast majority of NO_x emitted by a combustion source is derived from nitrogen contained in the combustion air. Nitrogen oxides can also be derived from nitrogen compounds contained in the fuel (fuel NO_x).

The primary methods of reducing emissions of nitrogen oxides are through reduction in combustion temperature and low excess air. The reaction that forms NO in combustion can be minimized by maintaining as low a combustion temperature as possible. Low excess air reduces NO_x formation by using the minimum amount of air necessary to combust the fuel, therefore, less oxygen is available for the formation of NO_x . Incomplete fuel combustion and concomitant increased emissions of CO and hydrocarbons is an obvious problem with low excess air combustion. Two stage combustion is a process that utilizes both low excess air and low temperature controls. In the first stage the fuel is fired at a relatively high temperature in a substoichiometric amount of air, e.g. 90 to 95% of the stoichiometric requirement. In the second stage fuel burnout is completed at a relatively low temperature. Nitrogen oxides are limited in the first stage by the absence of excess oxygen and in the second stage by the low temperature. The peak flame temperature in a combustion process can also be

reduced by injection of recirculated flue gas (which has a reduced oxygen content), water, or steam.

Nitrogen dioxide can also be formed by bacterial action. The generation of NO_2 by fermentation of ensilage containing nitrate is a striking example.

Chemistry of Formation and Reactions

The conversion of NO to NO_2 occurs as part of the oxidation of organic compounds initiated by reactive species such as the OH radical.⁷ Figure 202.7 illustrates this process using ethane as the simplest example. Alkyl peroxy (RO_2) and hydroperoxy (HO_2) free radicals which oxidize NO to NO_2 are generated in this process. A substantial percentage of the time the OH radical is regenerated to continue the reaction.

Once NO has been converted to NO_2 , a variety of reaction paths are available⁷ (Figure 202.8). When there are sufficient concentrations of both ozone and NO_2 , the nitrate radical (NO_3) and dinitrogen pentoxide (N_2O_5) are formed. Like OH , NO_3 reacts with hydrocarbons to initiate their oxidation. NO_3 photolyzes rapidly; therefore, its chemistry is important only at night when it is the driving force of atmospheric chemistry (and the photolytic production of OH is shut down).

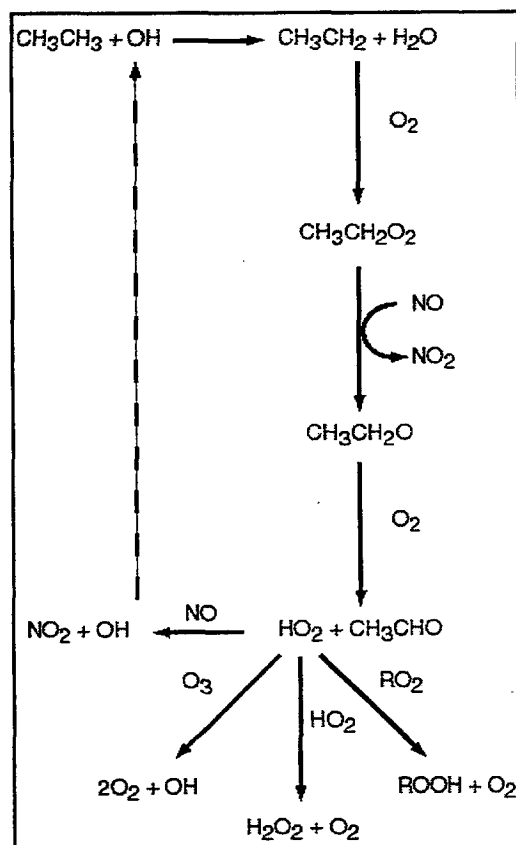


Figure 202.7 Example of the Role of Organic Compounds in the Conversion of NO to NO_2 Reference 7

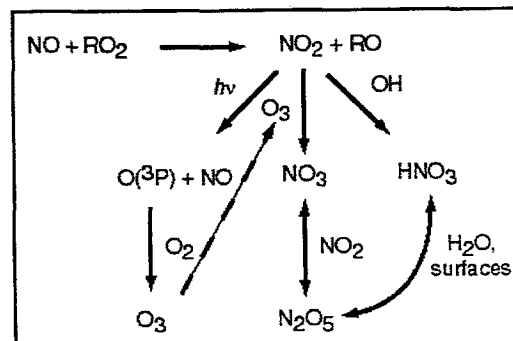


Figure 202.8 Summary of the Major Reaction Paths for NO_x in Air⁷

The formation of nitric acid on wet surfaces, including those of aerosol particles, is the major end product of nitrogen chemistry. The nitric acid can be deposited as wet or dry acid deposition (see section 202.3.6) or can react with alkaline particles and gases (such as ammonium [see section 202.2.4]) to be deposited as a neutralized nitrate compound. Nitrogen oxides have a lifetime of approximately one day with respect to conversion to nitric acid.²⁶

The most important aspect of the chemistry of NO_2 is its influence on ozone production. Whether or not ozone is produced by VOC-NO_x reactions in the air depends critically on the NO (and concomitantly NO_2) concentrations.

Health Effects

Nitrogen dioxide can irritate the lungs, cause bronchitis and pneumonia, and lower resistance to respiratory infections.²⁴ For exposures ranging from several minutes to one hour, a level of 50 to 100 ppm of NO_2 causes inflammation of lung tissue lasting for 6 to 8 weeks. Exposure to 150 to 200 ppm causes "bronchiolitis fibrosa obliterans", a condition that is usually fatal within three to five weeks after exposure. Death generally results within 2 to 10 days from exposure to 500 ppm or more.²⁷

At lower exposure levels more in line with ambient exposures, the primary effect of NO_2 is to increase the susceptibility of the airways to other triggers.²⁷ For instance, 400 ppb of NO_2 for one hour has been shown to increase an asthmatic's response to allergen challenge. This suggests that NO_2 may act via a permissive mechanism (that is, allowing a second stimulus to exert a greater effect by priming the airway in some way) that causes the lining of the airway to become "leaky" and allow allergens etc. to penetrate the airway wall and cause greater effect than they otherwise would.

Biological Effects

The primary biological effects of NO_2 , other than its human health effects, can be related to its associated secondary pollutants (ozone, nitrate, and nitric acid deposition [for additional information see the sections of this manual that describe those pollutants]). However, since the 1970's scientists have realized that seeds of some plants that inhabit fire-prone areas and grow best on freshly burned-over land can be triggered to germinate by exposure to smoke. Nitrogen dioxide has been isolated as a key component of smoke that spurs the generation of Yellow Whispering Bells, an annual herb that springs up after fires in California's chaparral and sage scrub communities. Of important concern is that the concentrations of nitrogen dioxide observed in Los Angeles have been

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shown to trigger germination in the absence of fire.²⁹ This could be ecologically devastating since the plants may be germinating under conditions in which they are not adapted for growth.

Material Effects

As with the primary biological effects of NO_2 , most material effects can be related to its associated secondary pollutants (ozone, nitrate, and nitric acid deposition [for additional information see the sections of this manual that describe those pollutants]).

202.1.6 Lead

Ambient concentrations of lead have dropped precipitously in the past 25 years. However, due to its physical and cognitive developmental toxicities, lead can still pose a significant problem where elevated concentrations still exist.

Lead is one of several metals that were discovered early in human history. Other metals in this group include iron, copper, tin, gold, and silver. The usefulness and importance of lead has continued to grow through time (Figure 202.9).

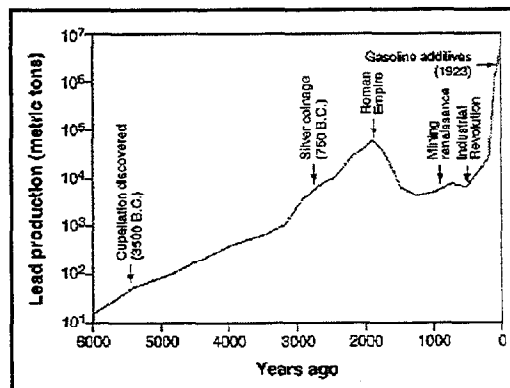


Figure 202.9 Historic Lead Production³¹

Some experts believe that lead was used as early as 5000 B.C., but the earliest firm archeological evidence is a figurine dating from about 3800 B.C. found in the Dardanelles area of Asia Minor. Lead was used for coinage by the Chinese about 2000 B.C. and was mined by the Greeks for coins, ornaments, weights, bullets for slings, and many other articles. The Egyptians and Romans used lead for pipes for the transport of water - an application that has continued to the present day.³⁰

Lead levels in peat bogs throughout Europe show an increasing use of lead in the ancient world.³¹ A breakthrough for extracting silver from lead ores, called cupellation, appeared about 3500 B.C. and greatly enhanced the popularity of silver which increased the emission of lead into the air. Lead emissions in-

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creased through the Roman era with increasing use of silver for coinage and lead for plumbing, weights, etc. During the Roman era lead usage was about 50,000 tons per year (Figure 202.9). After the fall of Rome lead usage fell greatly. From about 500 to 1500 A.D., lead usage was between 4000 and 7000 tons per year. The level of lead usage did not reach the Roman era level until the 1820's with the advent of the industrial revolution. Usage accelerated in the 20th century with the use of lead in gasoline and peaked in 1979 at approximately 4 million tons per year. Since then usage has declined.

In ancient times about 10 to 20% of the lead mined and cupelled was released into the air.³² Because lead was often a by-product of silver production, efforts were often made to convert it into "smoke" as a disposal mechanism. Improvements in smelting techniques reduced the emissions to about 2 to 5% of the lead content by the mid 19th century.

Description

Lead is a bluish-white metal of bright luster, is very soft, highly malleable, ductile, and a poor conductor of electricity. It is very resistant to corrosion; lead pipes from the Roman era are still in use today². Care must be used in handling lead since it is a cumulative poison.

The Latin word for lead is plumbum, from which the modern English words "plumber" and "plumbing" are derived. The chemical symbol for lead, Pb, was also derived from the Latin word.

Sources

In ancient times up to the introduction of leaded gasolines in the early 20th century, industrial metals processing sources dominated the lead emissions into the air. In the 1970's and 80's lead was phased out of gasoline. Today metals processing again dominates is the source of lead emissions¹⁰. Control programs substantially reduce lead emissions from stationary sources. For example, lead emissions from primary and secondary lead smelters have dropped by about 91% since 1970.²⁴

Between 1987 and 1996, ambient lead concentrations decreased by 75% and total lead emissions decreased by 50%. Since 1987 lead emissions from automobiles have decreased by 99% due to the phaseout of leaded gasoline¹⁰. The infrequent exceedances of the lead ambient air standards that remain tend to occur near large industrial lead sources rather than near highways as occurred in the recent past.

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There has been some concern, as yet unsubstantiated, that the introduction of electric cars will cause an increase in lead emissions from battery manufacture and recycling. Most electric cars, however, will probably use advanced batteries, such as nickel-metal hydride, that do not use lead.

Chemistry of Formation and Reactions

Lead is a naturally occurring element. As such, lead may be emitted by sources; however, it is not formed by the process, rather lead that is part of the fuels, ores, or raw materials may be released into the air. Lead also does not participate in atmospheric chemistry.

Health Effects

Much has been made of the effects of lead based paints; however, only about 5 to 10% of the ingested lead actually enters the blood stream. Inhaled lead is far more serious. Fine particles containing lead are retained in the alveoli of the lungs and are absorbed by the body with an efficiency of about 40%. Thus, a small quantity of lead inhaled can be far more serious than a larger quantity ingested.³³

Lead is one of the more insidious air criteria pollutants. Since it accumulates in the blood, bones, and soft tissues, a small chronic exposure can have more health effects than would otherwise be expected.

Lead can adversely affect the kidneys, liver, nervous system, and other organs. Excessive lead exposure can cause neurological impairments such as seizures, mental retardation, and/or behavioral disorders. Children and developing fetuses are especially vulnerable to the effects of lead exposure. Even at low doses, exposure is associated with damage to the nervous system of fetuses and young children, resulting in learning deficits and lowered IQ. Studies have also indicated lead as a factor in high blood pressure and heart disease.¹⁰

Biological Effects

Lead deposited on leaves represents a hazard to grazing animals. It appears that the susceptibility and symptoms of animals exposed to lead pollution are about the same as for human exposure.¹⁰

Material Effects

The primary material effect of lead pollution is soiling due to the particulate nature of lead deposition.

202.2 NON-CRITERIA POLLUTANTS

There are a number of air pollutants that, while not classified as criteria pollutants, are often monitored and are very important for health and welfare. Some of the non-criteria pollutants are precursors to criteria pollutants (i.e. VOC and NO as precursors to ozone), some are active in atmospheric chemistry that forms secondary particulate (ammonia), and some are hazardous in their own right (hydrogen sulfide; other toxic air contaminants, such as those covered under California Statute 2588, the Air Toxic Control Measures program, and the U.S. EPA National Emission Standards for Hazardous Air Pollutants program).

202.2.1 Hydrocarbons

The most important reason that hydrocarbons are monitored is that they play a key role in the formation of ozone. Some hydrocarbon compounds are also toxic and present a direct health hazard, those compounds will be discussed in the following section (202.2.2 Toxics).

As a class, hydrocarbon air pollutants are variously called: non-methane hydrocarbons (NMHC), non-methane organic carbons (NMOC), volatile organic

Table 202.3 Hydrocarbon Terms

| Class | | Definition |
|--|-------|--|
| Non-methane hydrocarbons | NMHC | Compounds containing hydrogen and carbon only |
| Hydrocarbons | HC | NMHC plus methane |
| Total Hydrocarbons | THC | Same as HC |
| Non-methane organic gas | NMOG | NMHC plus oxygenated compounds |
| Total organic gas | TOG | NMOG plus methane |
| Reactive organic gas | ROG | TOG minus exempt compounds, also $TOG \times FROG$ |
| Fraction of reactive organic gases | FROG | The weight fraction of those species designated as reactive |
| Volatile organic compounds | VOC | Total organ compounds minus exempted compounds having negligible photochemical reactivity (U.S.EPA term), $VOC = TOG \times FR_VOC$ |
| Fraction of volatile organic compounds | FRVOC | Weight fraction of those species designated as having negligible photochemical reactivity |

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compounds (VOC), total organic gases (TOG), and reactive organic gases (ROG). Each of these terms has a slightly different meaning when applied to ambient hydrocarbon pollutant concentrations (Table 202.3).

In most air pollution measurements, methane is not included since it is negligibly reactive. The U.S. EPA also does not include ethane.

Table 202.4 Types of Substituted Hydrocarbon Molecules

| Family | Comments and Examples |
|------------------------------------|---|
| Alcohols R-OH | Oxygenated fuels Reactive - bakery emissions |
| Aldehydes R=O H | Good preservatives (formaldehyde) Paints, glues, lube oils Aldehyde emissions contribute to formation of smog |
| Keytones O R-C-R | Industrial solvents, nail polish (acetone) Also result from breakdown of protein (bad breath) Absorbed through skin (MEK) |
| Organic Acids O R-C-OH | Acetic acid (CH ₃ COOH) Formic acid (ant bite) |
| Ethers R-O-R | Anesthetics (diethyl ether), solvents, medicines Gasoline oxygenates (MTBE) |
| Esters O R-C-O-R | Plastics, solvents in paints, resins, flavorizers Food oils |
| Amines R-N-... x | Nitrogen-containing organic compounds Characteristic, pungent odors Used for H ₂ S removal from natural gas |
| Mercaptans R-S-H | Source of many odor complaints Odorants for natural gas, butane, propane |

Table 202.5 Naming Conventions for Simple Hydrocarbons

| Number of Carbons | Prefix | Saturated | Unsaturated | |
|-------------------|--------|---|----------------------------------|--------------------------|
| | | Alkanes Single Bonded | Alkenes/Olefins Double Bonded | Alkynes Triple Bonded |
| 1 | meth- | methane CH_4 methyl- CH_3 - | --- | --- |
| 2 | eth- | ethane C_2H_6 ethyl- (acetyl-) | ethene (vinyl-) | ethyne (acetylene) |
| 3 | prop- | propane C_3H_8 propyl- | propene | propyne |
| 4 | but- | butane C_4H_{10} butyl- | butene | butyne |
| 5 | pent- | pentane C_5H_{12} | pentene | pentyne |
| 6 | hex- | hexane C_6H_{14} | | |
| 7 | hept- | heptane C_7H_{16} | | |
| 8 | oct- | octane C_8H_{18} | | |

Description

Hydrocarbons are a class of thousands of compounds comprised primarily of hydrogen and carbon. The properties of a hydrocarbon molecule depend on its structure (Table 202.4); i.e. the number of carbon and hydrogen atoms making up the molecule, how they are bound together (single, double, or triple bonds), the degree of branching of the molecule, and the presence of adjunct atoms (oxygen, nitrogen, sulfur, etc.). The name of the molecule also reflects its structure (Table 202.5).

Sources

Hydrocarbons are released into the atmosphere from a variety of man-made sources (eg. fossil fuel combustion, solvent evaporation) and some natural sources (eg. vegetations). The predominant source in California is automotive emissions.

Chemistry of Formation and Reactions

The number and complexity of volatile organic compounds (VOC) in the atmosphere is mind-boggling. Their participation in ozone formation is an additional extremely complex interplay between hydrocarbons and nitrogen oxides which occurs through multiple mechanisms. However, the key point to is that VOC molecules provide a source of free radicals to propagate the series of chemical reactions that form ozone. Therefore, the VOC molecules of greatest concern are those that are highly reactive. While reactivity information will describe the likelihood that a VOC will react to form ozone-producing radicals, it does not necessarily indicate the amount of ozone that will be produced by that particular hydrocarbon compound.

A study conducted by the Swedish Environmental Research Institute classified 75 organic compounds according to their ability to form ozone.¹⁸ In this study 500 chemicals and more than 900 gas-phase reactions were modeled. The results showed that ethene (C_2H_4) and acrolein (C_3H_4O) had the potential to form the largest number of ozone molecules per molecule of carbon reacted. They also drew the following generalizations:

- Alkane, alkene (except ethene), and aromatic molecules generally produce 40 to 60% of the ozone produced by ethene.
- Alcohol, ketone, aldehyde (except acrolein), and ester molecules generally produce 10 to 35% of the ozone produced by ethene.
- Chlorinated VOC's (except for allyl chloride) produce little or no ozone.

One exception to the above generalizations is that larger alkanes may depress ozone formation by involving free radicals in reactions that produce stable compounds, thereby destroying the free radicals.

Production of ozone from hydrocarbons is dependent on ambient NO_x conditions. During high- NO_x conditions, slightly more than three kilograms of ozone may be produced by one kilogram of ethene. This compares to just over two kilograms of ozone per kilogram of ethene under low- NO_x conditions.¹⁸

Health Effects

Except for toxic hydrocarbons, little direct health effects have been documented for atmospheric hydrocarbons.

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Biological Effects

Few general biological effects of hydrocarbons, as with health effects, have been noted.

Material Effects

Again, few material effects can be directly attributed to hydrocarbons. The primary health, biological, and material effects resulting from atmospheric hydrocarbons are more closely tied to the secondary (ozone) pollutants due to the reactions of the hydrocarbons.

202.2.2 Toxics

The ARB defines toxic air contaminants as: "an air pollutant which may cause or contribute to an increase in mortality or in serious illness, or which may pose a present or potential hazard to human health."³⁴ An air contaminant that is a pesticide is regulated by the California Department of Pesticide Regulation. The state of California regulates air toxics through the Airborne Toxic Control Measure (ATCM) program. At the federal level, the U.S. EPA regulates toxic air contaminants through the National Emission Standards for Hazardous Air Pollutants (NESHAP) and Maximum Achievable Control Technology (MACT) programs.

The Clean Air Act (1990) requires the U.S. EPA to regulate toxic air pollutants from a list of source categories rather than by compound. The EPA is currently in the process of promulgating the NESHAP (MACT) standards. For additional information, see the ARB's Toxics Enforcement Manual.

Description

The toxic air pollutant category contains a wide variety of pollutants. In general, toxics are hydrocarbon based compounds that have been shown to be hazardous to human health. Many of the toxic compounds are complex hydrocarbons containing double bonds, aromatic ring structures, and oxygenated and halogenated moieties. Inorganic compounds such as asbestos, heavy metals (eg. cadmium, chromium, nickel, and mercury), and radionuclides are also listed toxic air pollutants. Most toxic air contaminants are present in the air at very low concentrations, although they may also be toxic at low concentrations.

Sources

The EPA has identified 176 source categories of toxic air pollutants. These include solvent use (eg. dry cleaning, wood furniture finishing, et.), heavy metals processing and use (eg. chromium electroplating, lead smelting, alumi-

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num production, copper production, etc.), and petroleum refining and handling (eg. refineries, bulk terminals, gasoline distribution, etc.)

Chemistry of Formation and Reactions

Most toxic air pollutants are volatile compounds that are emitted by vaporization from a process through evaporation, etc. Although some of the compounds participate in ozone formation, that is not the purpose of monitoring them under a toxics program.

Health Effects

By definition toxic air pollutants have a significant health effect. That health effect may differ depending on the compound in question. The effects may be hazards to general life and health, mutagenic effects, carcinogenic effects, or teratogenic effects.

Biological Effects

Many of the listed toxic air contaminants are toxic to plants and animals in addition to being toxic to humans.

Material Effects

In general, the listed toxic air contaminants do not have significant material effects.

202.2.3 Hydrogen Sulfide

Hydrogen sulfide (H_2S) is acutely toxic and great care should be exercised in its presence. It is common around oil and gas production and refining, sewage treatment, and stagnant, organic rich (swampy) waters. Levels above 150 ppm are considered to be life threatening.^{35, 36} Exposures in excess of 1000 ppm have been known to cause death in as little as one or two breaths. Whenever an inspector (or other person) is in an oil or gas field, refinery, or other area where H_2S may be present, they should be aware of the wind direction and escape routes.

Monitoring for H_2S may not be productive except in those few locations where it is expected to be found. In those locations it can be very important due to the nuisance potential odors and toxicity of H_2S .

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Description

Hydrogen sulfide is a colorless, flammable, and highly corrosive gas with an offensive odor characteristic of rotten eggs. Since H_2S has a specific gravity (1.54 g/l @ 0°C , 1 atm.³⁵) greater than air, it settles into low areas, dips, depressions, ditches, etc. The odor threshold is reported to be about 25 ppb (35 $\mu\text{g}/\text{m}^3$); levels in the 3 to 5 ppm range cause an offensive odor. At concentrations around 100 ppm, no odor is detected due to the loss of olfactory sensation, resulting in the loss of warning properties.³⁶

Sources

Natural sources constitute approximately 90% of the atmospheric burden of H_2S .^{Reference 35} Ambient concentrations due to natural sources are estimated to be between 0.11 and 0.33 ppb (0.15 and 0.46 $\mu\text{g}/\text{m}^3$). It is produced in nature primarily through the decomposition of organic material by bacteria. It develops in stagnant water that is low in dissolved oxygen, such as in bogs, swamps, and polluted water. Hydrogen sulfide can also occur naturally from natural gas and petroleum seeps, sulfur deposits, volcanic gases, and sulfur springs.

Hydrogen sulfide is the most common impurity in natural gas and petroleum. In the oil and gas industry H_2S may be emitted or released during exploration, development, extraction, treatment, storage, transport, or refining. In the gas and oil production and processing industries sudden lethal concentrations of H_2S can occur. Additional information is contained in the ARB's Oil Field Production CAP manual.

If oil or gas contains H_2S , it is said to be "sour." In California, oil fields range up to 27% weight H_2S . Up to 42% (by volume) H_2S has been found in gas fields in Wyoming.

Chemistry of Formation and Reactions

Most hydrogen sulfide is naturally formed, although it may be emitted via an industrial process (i.e. oil and gas production and processing). It may also be produced in stagnant waters, waste water processing, and sewage processing. Hydrogen sulfide is primarily produced by the decomposition of organic matter by bacteria. In the case of oil and gas, the H_2S has been trapped by geology. In the case of stagnant waters and waste water and sewage processing, the H_2S may be emitted as it is produced.

In the oil and gas industry, H_2S is usually removed from the product by adsorption in an alkanolamine solution. It is then removed from the alkanolamine

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solution by heating and either burned in a flare or recovered as sulfur. Burning H_2S in a flare converts it to sulfur dioxide (SO_2). Sulfur recovery is frequently accomplished by taking advantage of the reaction of H_2S with SO_2 to form elemental sulfur. A sulfur recovery unit can remove 99.9+% of the H_2S in a waste gas stream at a gas processing plant.³⁷

Hydrogen sulfide will oxidize to form SO_2 .

Health Effects

There are several incidences in the United States each year of deaths of workers exposed to H_2S . Symptoms of exposure include: irritation, breathing disorders, nausea, vomiting, diarrhea,

giddiness, headaches, dizziness, confusion, rapid heartbeat, sweating, weakness, and profuse salivation. As can be seen in Table 202.6, significant health effects can result from exposure. At high concentrations (1,000+ ppm) fatalities can result from one or two breaths. There have been cases where rescue personnel have developed H_2S poisoning due to exposure during mouth-to-mouth resuscitation.

Within the body H_2S is metabolized by oxidation, methylation, and reaction with metallo- or disulfide- containing proteins. Because of the rapid oxidation in the blood, H_2S is not considered a cumulative poison. The damage observed to

Table 202.6 Health Effects of H_2S Exposure³⁵

| Clinical Effect | Level of Hydrogen Sulfide | |
|--|---------------------------|-------------------|
| | ppm | mg/m ³ |
| Odor perception threshold | 0.025 | 0.035 |
| Offensive odor (rotten egg) | 3 - 5 | 1.4 - 7 |
| Offensive odor (sickeningly sweet) | 30 | 42 |
| Occupational exposure limit (OEL) | 10 | 14 |
| Corneal inflammation (6 -7 hour exposure) | 10 | 14 |
| Serious eye injury | 50 - 200 | 70 - 280 |
| Olfactory paralysis | 100 - 250 | 140 - 350 |
| Organ and nervous system damage | 250 | 350 |
| Pulmonary edema, threat to life | 300 - 500 | 420 - 700 |
| Acute intoxication | 500 - 1000 | 700 - 1400 |
| Respiratory paralysis, collapse, and death | 1000+ | 1400+ |

persist after H₂S exposure is indistinguishable from the effects of systemic anoxia or ischemia of the brain or heart.

Biological Effects

The above health effects discussion should give a good background on the effects of hydrogen sulfide on wildlife, although the concentrations resulting in effects may be different. Frequently the first indication that an inspector will have that a remote oil or gas production facility has excess H₂S emissions will be that there will be dead birds around the plant; in which case the inspector must proceed with care.

Material Effects

Hydrogen sulfide is extremely corrosive to metals and will quickly corrode equipment in contact with it. In oil and gas production, H₂S is removed from the produced hydrocarbons in one of the first steps of product clean-up to minimize equipment damage.

202.2.4 NO, Ammonia, and Other Nitrogenous Compounds

While not part of the criteria pollutant program, these nitrogen compounds are important in their own right and to ozone, particulate matter, and other pollutant formation and cycles. Although often not recognized, ecologically, deposition of nitrogen compounds can be very damaging.

Description

The common thread in this grouping of pollutant is that they contain nitrogen. Seven oxides of nitrogen are known to occur in the atmosphere: NO, NO₂, NO₃, N₂O, N₂O₃, N₂O₄, and N₂O₅.⁴³ NO_x is generically used as the sum of NO and NO₂. These compounds are generally transformed and cycled within the atmosphere through the nitrate radical (NO₃), organic nitrates, and dinitrogen pentoxide (N₂O₅), eventually forming nitric acid. NO and related compounds were discussed in the sections that discussed ozone formation (202.1.4 and 202.3.1). Since most nitrate is a secondary pollutant, it also will be discussed elsewhere, i.e. in section 202.3.2 under the secondary pollutant category.

Ammonia is a colorless, corrosive, alkaline gas with an extremely pungent odor. It can be liquefied by compression (a form frequently used in agriculture when fertilizing fields) and will attack some forms of plastics, rubber, and coatings. Ammonia is very soluble in water, ether, and chloroform and moderately soluble

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in alcohol. It quickly forms ammonium ion on acidic particles and in aqueous droplets. Ammonia is also a good solvent.

Sources

Ammonia is used in refrigeration, blueprinting machines, and as a neutralizing agent in the petroleum industry. It is also used in the manufacture of fertilizers, nitric acid, explosives, plastics, fuel cells, rocket fuel, synthetic fibers, dyes, and other chemicals. Stationary source emissions can occur from processing of guano, purification of refuse, sugar refining, tanneries, and in unpurified acetylene.

The primary stationary sources that have reported emissions of ammonia in California are electric, steam and air conditioning, and petroleum refining facilities.³⁸

The total stationary source emissions of ammonia are estimated to be about 20 million pounds (1995).

A common use of ammonia in stationary sources in California is for NO_x control in turbines. Selective catalytic reduction (SCR) uses ammonia and a catalyst to remove NO_x from the emissions. Selective non-catalytic reduction (SNCR) operates similarly, however, SNCR operates at a higher temperature and does not use a catalyst. An SCR or SNCR unit must be carefully operated to prevent excessive ammonia emission (ammonia slip). During source testing of turbines ammonia is often tested in addition to NO_x , etc.

In many areas ammonia emissions are almost exclusively associated with agricultural activities, particularly intensive livestock feeding operations. For example, in North Carolina agricultural ammonia emissions constitute over 40% of the nitrogen compounds emitted into the air.³⁹ The predominant agricultural emission is from the decomposition of urine and manure.

Chemistry of Formation and Reactions

Ammonia exists in the atmosphere in the gas phase, and is subject to gas phase reactions with photochemically produced hydroxyl radicals, wet and dry deposition, and reaction with gaseous nitrates and sulfates. This last is important in neutralizing acid deposition. Ammonia will convert acidic nitrate and sulfate vapors and aerosols into neutralized ammonium nitrate and ammonium sulfate particles.

Health Effects

Ammonia is irritating to the eyes and respiratory tract. High concentrations cause conjunctivitis, laryngitis, and pulmonary edema, possibly accompanied by a feeling of suffocation.³⁸ Irritation of the nose occurs at about 400 ppm and irritation of the throat occurs at about 700 ppm.³⁶

Biological Effects

Deposition of nitrogen compounds can have a significant ecological effect. At first one would think that nitrogen, as a fertilizer, would be a benefit to the environment; however, that fertilizing effect can greatly alter the balance of species. For example, fertilizing an ecosystem may cause species to be able to invade an area where they hadn't been able to survive before, to grow exorbitantly, or to crowd out existing species (or be crowded out).

Soil microbes can more readily use ammonium than nitrate. Therefore, if there is a surfeit of ammonium, plant may be able to satisfy their nitrate requirement without using nitrate. Nitrate (both from the soil and from nitrate air pollution deposition) will then migrate through the soil and run off in streams.⁴⁰ Excess ammonium, nitrate, and other nitrogenous compounds can also alter the rate of decomposition of plant litter and soil organic matter.⁴¹

Material Effects

Nitrogenous compounds can be acidic (e.g. nitric acid) to basic (e.g. ammonia). Therefore a wide variety of effects is possible. The amount and balance between ammonium, nitrate, and other nitrogenous compounds can significantly alter soil chemistry and biochemistry resulting, for example in leaching of essential cations (e.g. calcium and magnesium) and mobilizing of aluminum ions.

202.3 SECONDARY POLLUTANTS

Secondary pollutants are those that are not emitted in their pollutant form. Usually secondary pollutants are formed through atmospheric chemistry. Many of the secondary pollutants discussed in this section have been discussed in part in the criteria and non-criteria pollutant sections above. The secondary pollutants may be either more or less important to health and welfare effects.

202.3.1 Ozone

Ozone is the most common secondary pollutant of the much larger classification of photochemical air pollutants (Figure 202.10). As was discussed in the previous sections, photochemistry is important in the formation, persistence, and

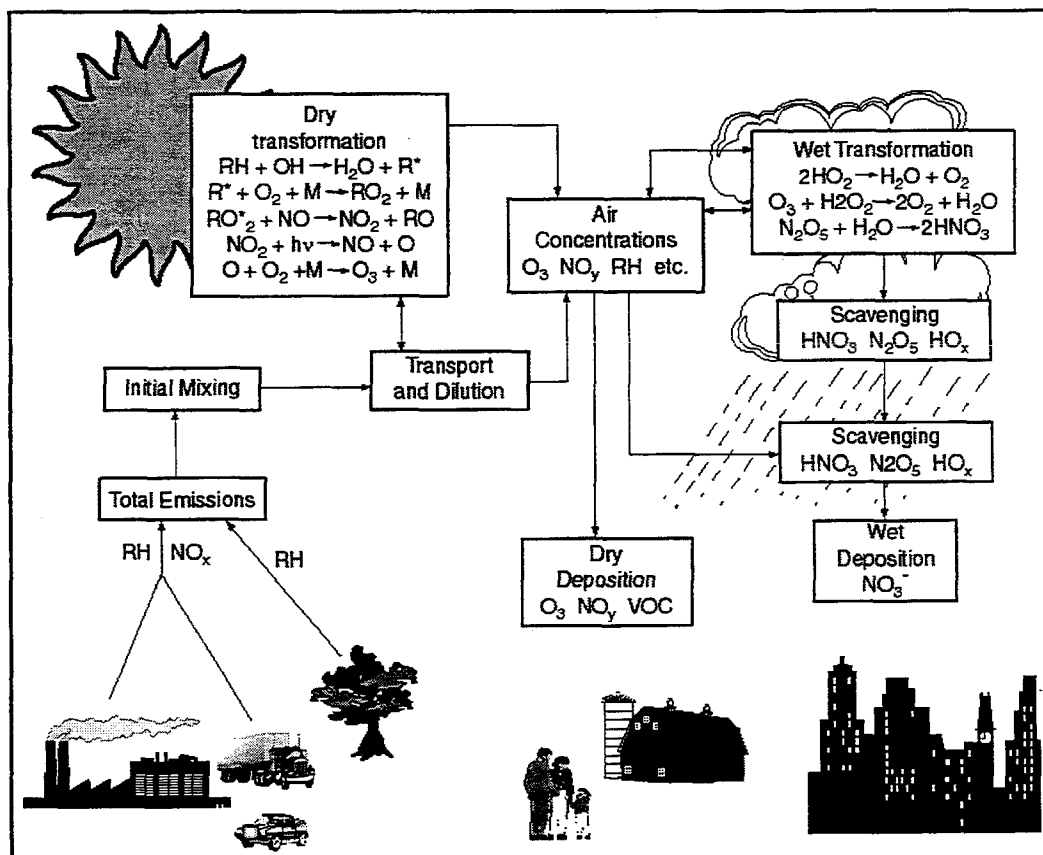


Figure 202.10 Photochemical Air Pollution From Emission to Deposition

removal of a number of pollutants; particularly ozone, hydrocarbons, and nitrogen oxides.

Ozone produced by reactions in the troposphere between NO_x and VOC's is the primary constituent of photochemical smog. The orange-brown color to the atmosphere observed in many cities is the telltale signature of photochemical smog, particularly NO₂. The complexity of ozone producing reactions makes ozone reduction extremely difficult. Much of the difficulty arises from the vast number of VOCs and their photochemical reactivity. Large alkane molecules may actually depress ozone production by involving free radicals in reactions that produce stable compounds, thereby destroying the free radicals.

A significant problem in devising plans to control ozone result from the fact that reducing NO_x or VOCs may increase, rather than decrease, ozone concentra-

tions. Figure 202.11 illustrates this problem; although the exact nature and values of ozone/ NO_x /VOC will vary depending on the photochemical dynamics.

The ratio of VOCs to NO_x plays an important role in the formation of ozone. When the ratio is low (in the VOC limited region of Figure 202.11), NO_x (and consequently NO) concentrations are high while VOC concentrations are low. Since relatively few VOCs are available to participate in the ozone formation

cycle, ozone concentrations remain in check by the reaction of NO with ozone to form NO_2 and O_2 . Further increases in NO_x concentrations may decrease ozone by accelerating the scavenging reaction. This is known as the "NO_x inhibition effect."

At high VOC to NO_x ratios (NO_x limited region of Figure 202.11), insufficient NO_x is available to propagate the excess ozone formation cycle. Due to this "hydrocarbon saturation" effect, additional hydrocarbon emissions will not increase ozone formation.

Figure 202.11 is divided into three areas in which emission control strategies will have characteristic effects:

- VOC limited region -- VOC/ NO_x ratio of less than 4:1:
Decreasing NO_x increases ozone
Decreasing VOCs decreases ozone
- Knee region -- VOC/ NO_x ratio greater than 4:1, but less than 15:1:
Decreasing NO_x or VOCs decreases ozone

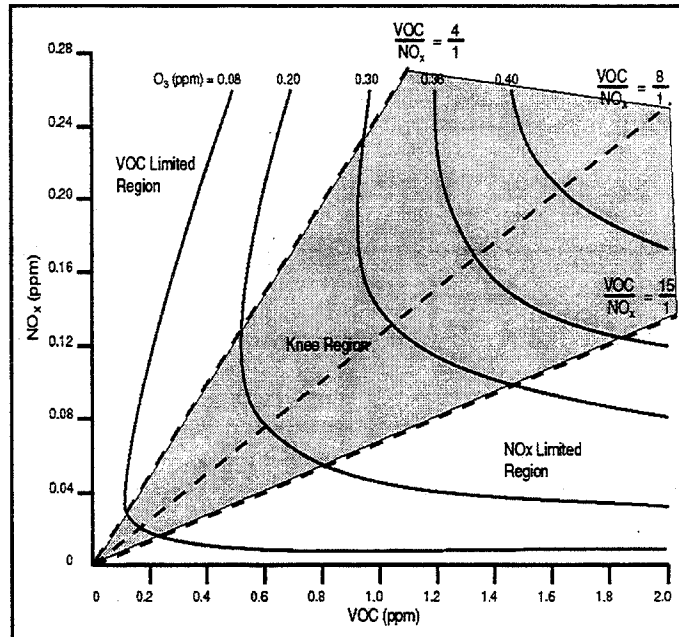


Figure 202.11 Isopleths of Ozone Formation as a Function of NO_x and VOC Concentrations

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- NO_x limited region -- VOC/NO_x ratio greater than 15:1:
 - Decreasing NO_x decreases ozone
 - Decreasing VOCs has no effect on ozone

In general large cities in the northern United States have VOC/NO_x ratios less than 10, while smaller cities and cities in southern regions have ratios greater than 10.

In Los Angeles, studies have measured the effects of varied VOC and/or NO_x concentrations on ozone formation. Three possible strategies emerged to reduce ozone by 50%. In the first case a reduction of VOCs by 65% and no reduction of NO_x would obtain the desired 50% ozone reduction. This case does not, however, address the problems posed by nitric acid and other nitrates derived from atmospheric chemistry of the NO_x. In the second case, ozone could be reduced by 50% by reducing NO_x by 85% with no reductions in VOCs. In the third case, reducing both VOCs and NO_x by 80% is required to reduce ozone by 50%.

An additional factor to consider when formulating ozone reductions is the effect on downwind transport areas. As an air mass is transported the ratio of VOC to NO_x increases due to the fact that NO_x species have a shorter lifetime than most hydrocarbons.⁴² Ozone concentrations may show a depression early in transport due to the NO_x scavenging and an enhancement later when the NO_x concentrations have been reduced.

Stratospheric ozone reduction and global warming may present additional problems in ozone control. Reduced stratospheric ozone will allow additional ultraviolet radiation to reach the troposphere, increasing tropospheric ozone concentrations by increasing photochemical activity and increasing temperatures. Global warming may also increase the potential for ozone formation by increasing the ambient temperature. Attaining the standards for ozone in either of these cases may require additional emission reductions.

202.3.2 Nitrate

Nitrate (NO₃⁻), as nitric acid (HNO₃), is the predominant end product of atmospheric nitrogen oxide chemistry. Nitrates are important in both gas and particulate air pollution.

Description

Nitrate air pollution comes in two primary forms: nitric acid vapor and particulate nitrate ion. Nitric acid can be removed from the atmosphere via wet or dry deposition. In the presence of ammonium, nitrate forms ammonium nitrate particles.

Sources

The main mechanism that removes NO_x from the atmosphere is the conversion of NO and NO_2 into nitric acid.⁴³

Chemistry of Formation and Reactions

Nitric acid is formed in the daytime through reaction of NO_2 with the hydroxyl radical (OH) and in the nighttime through reactions which form dinitrogen pentoxide, which then hydrolyses to produce HNO_3 ^{Reference 43} (Figure 202.8 and 205.[OH]). Gaseous nitric acid formed in these reactions may then undergo wet or dry deposition. During transport of an air mass through rural areas downwind of cities, it frequently has ammonia admixed. With the addition of ammonia nitric acid forms particulate phase ammonium nitrate (NH_4NO_3). Nitrates can also react at airborne particle surfaces to form nitrate salts, such as sodium nitrate. Conditions that favor aerosol nitrate formation include high nitric acid concentrations, high ammonia or salt particle concentrations, low temperatures, and high relative humidity.

The particulate phase ammonium nitrate is volatile at high ambient temperatures.⁴⁴ At temperatures greater than 30°C , most nitrate will be in the gas phase as nitric acid; while at temperatures lower than 15°C particulate ammonium nitrate is stable.

The equilibrium between the gas phase nitric acid and particulate phase ammonium nitrate is dependent on the relative humidity and concentrations of ammonium and nitric acid, but temperature is by far the most important factor.⁴³

During hot weather (or cooler weather if the sampler is heated by exposure to strong sunlight) a significant amount of particulate mass may be lost by the volatilization of ammonium nitrate. This may also happen if the filter is heated by air compression as it is drawn through the filter.

Positive artifacts may occur in nitrate sampling when oxides of nitrogen and nitric acid are drawn through an alkaline filter or deposit on the filter.

Health Effects

Nitrate deposition to surface water supplies can increase nitrate and nitrite concentrations in drinking water (although agricultural runoff constitutes a much greater source of contamination). The primary adverse health effect associated with exposure to nitrite (nitrate can be converted into nitrite in the body) is to cause methemoglobinemia. Methemoglobinemia occurs when nitrite oxidizes iron (Fe^{2+}) in the blood into Fe^{3+} , a form that does not allow oxygen transport and can cause brain damage. This conditions is rare in adults, but can be a concern in infants.

In the laboratory, nitrates can readily react with common organic chemicals and ozone in the presence of light to form a number of mutagenic and carcinogenic transformation products. Results of bacterial and mammalian cell bioassays indicate the transformation products are able to alter DNA; however, more research is needed to understand the potential public health impacts.

Biological Effects

Nitrate deposition in many cases has a fertilizing effect. Fertilization, however, is not necessarily a good thing from an ecological standpoint. It can alter inter-species competitive relationships, shifts in plant species composition, and decreases in species diversity. Nitrate leaching of soil mineral nutrients can cause nutrient imbalances (such as depressed Ca:Al and Mg:N ratios in foliage) which lead to decreased growth and vigor and increased mortality.

The biological effects of nitrate deposition were also further discussed previously in section 202.2.4.

Material Effects

The primary material effect of nitrate deposition is related to deposition of nitric acid. This topic will be further discussed in section 202.3.6.

202.3.3 Sulfate

Almost all atmospheric sulfate is in the particulate phase and result from the atmospheric conversion of sulfur oxides (principally SO_2) from the gas phase to the particulate phase.

Description

Ammonium sulfate ($(\text{NH}_4)_2\text{SO}_4$), ammonium bisulfate (NH_4HSO_4), and sulfuric acid (H_2SO_4) are the most common forms of sulfate found in the atmosphere.

These compounds are water soluble and found primarily in the $PM_{2.5}$ size fraction particulate.⁴⁴ Sodium sulfate (Na_2SO_4) may be found in coastal areas where sulfuric acid has been neutralized by sea salt ($NaCl$) or formed from sulfate from sea water. In the coarse fraction, gypsum (Ca_2SO_4) and some other geological compounds containing sulfate may also be found. The geologic sulfates do not dissolve in water as easily the anthropogenic sulfates.

Sources

Although there are a few direct anthropogenic sulfate sources (such as elemental sulfur, sulfuric acid, and fertilizer manufacturers), most sulfate is a secondary pollutant formed through atmospheric chemistry from sulfur oxide (SO_2) emissions. Some natural sulfate may originate from direct sulfate from sea water in areas near the shoreline or as sodium sulfate from the reaction of SO_2 with sodium from sea salt spray. Natural sulfate may also result from emissions of the dust of pulverized sulfate rock such as gypsum.

Chemistry of Formation and Reactions

Gas phase conversion of SO_2 to aerosol sulfate occurs primarily through reaction with hydroxyl (OH) radical. Reaction with HO_2 and acetyl radicals (RO_2) also convert significant SO_2 to sulfate.⁴⁵ Since the OH , HO_2 , and RO_2 species are part of the photochemical processes in the atmosphere, the formation of sulfate is related to the photochemistry of ozone, hydrocarbon, and nitrogen oxide. This has been confirmed by various studies. Sulfuric acid (H_2SO_4) vapor molecules rapidly transfer to the particulate phase by nucleation or condensation onto existing aerosol surfaces.

The maximum rate of SO_2 oxidation is strongly related to the initial NMHC/ NO_x ratio and solar radiation.⁴⁵ However, the maximum sulfate concentration is independent of the NMHC/ NO_x ratio, rather related to the SO_2 concentration.

In the presence of fogs or clouds, aqueous phase conversion of SO_2 to sulfate occurs. Uptake and oxidation of SO_2 is abetted by dissolved peroxide and ammonium. As SO_2 is absorbed by a droplet, the pH falls. At low pH further absorption of SO_2 is reduced, or even reversed (i.e. emission of SO_2 from the droplet). Absorption of ammonium by the droplet will raise the pH allowing additional SO_2 absorption. In the eastern U.S. fine particulate may be more than 60% ammonium sulfate and/or sulfuric acid.⁴⁶ In the western part of the country the fraction is lower, however still in the 25% to 65% range.

Health Effects

Taken as a whole, the available epidemiological evidence shows a strong relationship between sulfate aerosols, and other fine particulate matter, and respiratory related illness in the United States.⁴⁷ Many of the health effects are extremely difficult to separate from other health effects of particulate matter. The health effects appear to be primarily related to exposure to acid sulfates (or the formation of acid sulfates after deposition in the respiratory tract). Acute exposure to acidic sulfates can increase airway resistance, decrease pulmonary function, and increase responsiveness to bronchoconstrictors, especially in asthmatics. Considerable variability between studies suggests a high degree of uncertainty about what exposures will cause these effects.

In adult asthmatics inhalation exposure to $450 \mu\text{g}/\text{m}^3$ sulfuric acid for 16 minutes results in increased airway resistance, whereas exposure to $100 \mu\text{g}/\text{m}^3$ causes no response. In adolescent asthmatics, $68 \mu\text{g}/\text{m}^3$ for 40 minutes resulted in increased airway resistance. No effect was observed in nonasthmatics in exposure up to $1000 \mu\text{g}/\text{m}^3$.

Biological Effects

Animal inhalation studies indicate responses similar to human effects (although species differences exist). Responses of aquatic animals (e.g. fish, etc.) are predominantly due to the pH of the water.

Effects of sulfate on vegetation are predominantly related to the effects of acid deposition on soil nutrient and mineral availability and cycling. Ammonium sulfate and ammonium bisulfate may also have a fertilization effect from the nitrogenous moiety. Less frequently, the sulfate moiety may also have a fertilization effect.

Material Effects

The most significant material effects of sulfate air pollutants are related to the deposition of sulfates in the sulfuric acid form. Sulfuric acid can corrode and weaken building materials and statuary. Sulfuric acid can increase weathering of natural stone outcroppings. It will also change the mineral ionic content of rainfall runoff and their availability in soils.

Sulfate makes up the largest fraction of fine mass particulate matter. Most specifically, the particulate matter most associated with sulfates is the very fine fraction ($\sim\text{PM}_{10}$) that is most optically active. Hazes and reduced visibility are often highly correlated to sulfate content of particulate matter.

In an effect of sulfate particulate related to hazes and visibility reduction, fine sulfate particulate matter in the stratosphere has been shown to enhance the earth's albedo, temporarily offsetting the effects of global warming.

202.3.4 Particulate

As was discussed in the ozone, nitrate, sulfate, and hydrocarbon sections, secondary particulate matter, especially fine particulate, is related to the chemistry of a

wide variety of gaseous and particulate emissions. Figure 202.12 illustrates some of the interactions and formation processes of fine particulate.

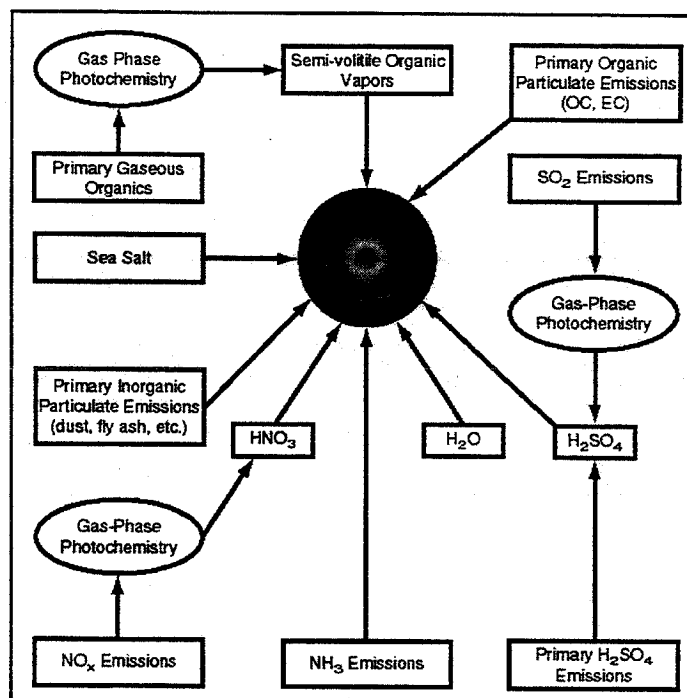


Figure 202.12 Contributions to Atmospheric Particulate Matter

Once formed, the particulate does not quit participating on atmospheric chemistry. Reactions with atmospheric gases, water vapor, and other particles continue to modify the particles. An example of this is that nitric acid vapor will react with sea-salt (NaCl) particles leading to chloride displacement and the generation of hydrochloric acid.

The reactant/product relations involved in the heterogenous chemistry of aerosols are generally inferred from bulk samples of atmospheric particles collected on filters. Unfortunately, the particulate matter is a complex collection of many different size particles with different compositions and chemistry.⁴⁸ The exact chemical speciation of individual particles cannot be determined from the bulk analysis. For example, although sulfate, nitrate, sodium, and ammonium ions may all be present in a bulk particulate sample, one cannot distinguish the particular composition and chemistry of individual particles. In addition, there will be chemical interactions between particles that may or may not occur when the particles are dispersed in the atmosphere.

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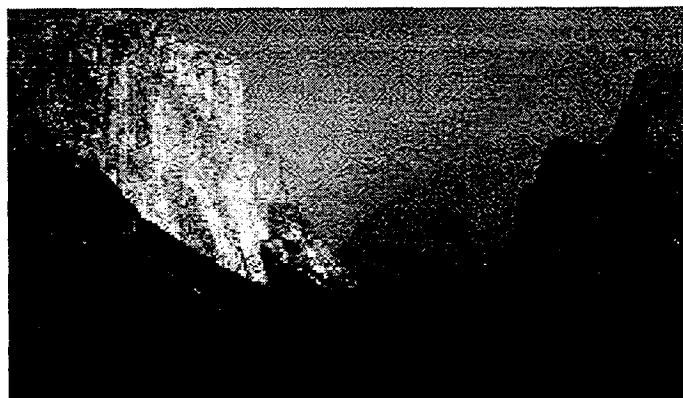


Figure 202.13 Effects of Visibility Impairment: Yosemite National Park Under Clear Conditions (top) and Hazy Conditions (bottom)

202.3.5 Visibility Impairment

In the 1977 Clean Air Act Amendments, Congress established the national goal of the prevention of any future (and the remediation of existing) visibility impairment in 156 national parks and wilderness areas. Visibility impairment is not an air pollutant per se, rather the manifestation of the effects other pollutants.

Visibility impairment is expressed in deciviews, visual range, or b_{ext} (the light extinction coefficient) and can be measured by transmissometer, nephelometer, or photographic image.

Visibility impairment is the yardstick by which the layman measures air quality every day. Visibility impairment is important for the enjoyment of scenic resources (a key factor for many national parks and forests) and as an indicator of other pollutants.

Description

Visibility impairment refers to the absorption and scattering (both into and out of the sight path) of light by air pollution. The sum of the absorption and scattering is referred to as atmospheric light extinction.⁴⁹ Hence, visibility impairment reduces the distance through which objects can be discerned. It includes degrading of color, clarity, and contrast of scenes (Figure 202.13).

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Ambient Air Monitoring

Visibility in the western United States is naturally greater than in the eastern U.S. This is partly due to the west being dryer than the east. Biogenic emissions are also lower in the west. Visibility is also greater in the west due to the lower density of industrial air pollution sources and the relative newer nature of the western industries (Figure 202.14).

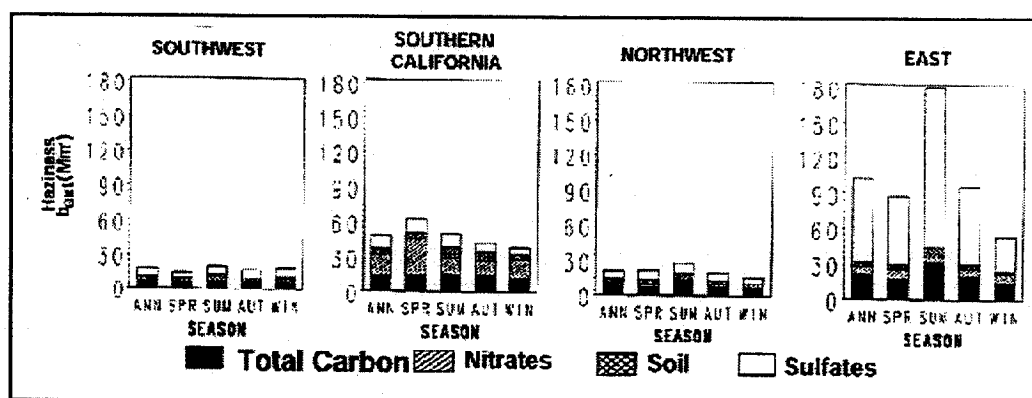


Figure 202.14 Contributions of Particulate Matter Composition To Visibility Reduction⁴⁸

The atmospheric visual range is governed primarily by the scattering and absorption of light by aerosol particles present in the atmosphere.⁸ The scattering by air molecules usually has only a minor effect, although it limits the maximum visual range to 100 to 300 km. Under natural, unpolluted conditions, the visual range in the eastern U.S. is about 100 to 125 km (60 - 80 miles) and in the west about 175 to 185 km (110 to 115 miles). The natural visibility is limited by clear air scattering and extinction by naturally occurring particulate (Table 202.7).⁴⁹

Table 202.7 Estimated Natural Visibility and Contributions to Natural Visibility Reduction

| | Visual Range: | |
|---|--|---|
| | East 60 - 80 Miles (8 - 11 dv) | West 110 - 115 Miles (4.5 - 5 dv) |
| Fine Particles | % Contribution to Visibility Reduction | |
| Sulfates ($(\text{NH}_4)_2\text{SO}_4$) | 9 - 12% | 5% |
| Organics | 19 - 38% | 10 - 15% |
| Elemental Carbon | 0.5 - 1% | 1% |
| Nitrates (NH_4NO_3) | 4 - 5% | 4% |
| Soil Dust | 2 - 3% | 4% |
| Coarse Particles | 6 - 8% | 11 - 12% |
| Clean Air (Rayleigh scattering) | 33 - 43% | 61 - 64% |

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The visual range is limited by two factors: visual acuity and contrast. We cannot read a book at 10 m because we have limited visual acuity; however, we can see stars at night due to their extreme contrast. The same stars cannot be seen in the daylight because the contrast is reduced to zero by the scattering of sunlight by air molecules. In most situations, it is the lack of apparent contrast that limits how far we can see objects.

Changes in visual range are not proportional to human perception. For example, a five mile change in visual range may be imperceptible or very obvious depending on the baseline visibility conditions. The deciview (dv) was adopted as a more meaningful visibility index. The deciview is linear with respect to perceived changes in visibility and is analogous to the decibel for sound. A one deciview change represents a change in scenic visibility that would just be noticed by most people. A deciview of zero equals clear air, deciviews greater than one represent increasingly impaired visibility.

The distribution and extent of pollutants in the atmosphere relative to the observer's sight path has a large effect on the appearance of visibility impairment. If the pollutants are uniformly distributed from the ground to a height well above the highest terrain, it is known as "uniform haze." If the top edge of the pollution layer is visible, as when the pollution is trapped below an inversion, it is called a "surface layer haze." A layer held above the ground is an "elevated layer haze." Plumes from stationary sources can be special cases of the elevated layer haze type, although it may not be possible to distinguish the plume from a surrounding elevated layer. It is possible to have combinations of pollutant distributions such as multiple layers superimposed on a uniform haze.

A uniform haze and a surface layer haze can be monitored from the ground by a variety of methods. Elevated layers must be monitored remotely from the ground or via instruments carried aloft.

Sources

Fine particles, particularly those in the 0.1 to 1.0 μm size range, are primarily responsible for reducing the visible range, the only gaseous emission that directly reduces visibility is nitrogen dioxide because it absorbs light.

Fine particles reduce the apparent contrast by scattering light. Light from an object is scattered out of the sight path and does not reach our eyes. However, sunlight is also scattered into the sight path and makes dark objects seem

brighter. The combined effect is to reduce the contrast between the object and its surroundings.

When the luminance of an object and its surrounding is equal, the contrast is zero and the object cannot be distinguished from the background. As we look at progressively more distant objects, such as a series of hills, each more distant hill is lighter in tone. At the limit of visibility the hills have the same brightness as the sky. The minimum contrast required to just distinguish an object from its background is called the *threshold of brightness contrast*.

The best current mean visibility (greater than 144 km (90 miles)) is found only in the inner mountain west and Great Basin regions.

Chemistry of Formation and Reactions

Visibility impairment is primarily a function of fine particulate matter and nitrogen dioxide. The chemistry and reactions of those pollutants is also applicable here.

High humidity can also affect visibility. Some particles, especially sulfates, are hygroscopic and accumulate water when the humidity is high. These particles often grow into just the right size to be very efficient at scattering light. They may also lose water when the humidity is low and shrink, possibly to a size below a visibly active size. Since the relative humidity tends to be higher, in the eastern U.S., as do the NO_2 and fine particulate concentrations, areas in the eastern US are more prone to visibility reduction than the western U.S.

Health, Biological, and Material Effects

Health, biological, and material effects are not generally directly related to visibility impairment; however, visibility reductions can usually be correlated to concentrations of other pollutants that do have significant effects. Visibility is also the means in which the public most directly relates to air pollution; i.e. the public often considers a hazy day as polluted and if the air is clear (regardless of the actual pollutant concentrations) it is considered to be unpolluted. Visibility is often very important in national parks, forests, and wilderness areas, many of which were established to showcase the beauty of the natural areas and vistas which may be obscured.

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202.3.6 Acid Deposition

Often referred to as acid rain, acid deposition pertains to the deposition of acidic compounds, principally nitric and sulfuric acids, although other acids may also contribute to the problem. Most acid deposition occurs when emissions of SO_2 and NO_x react in the atmosphere with water, oxygen, and oxidants to form the acidic components.

Description

The acidic compounds that are the focus of concern are usually not primary pollutants. Sulfur dioxide and nitrogen oxides, after they have been transformed by atmospheric chemistry, are the greatest contributors to acid deposition. Reaction of nitric acid with sea salt aerosol can produce gaseous hydrochloric acid (HCl).

Acid deposition may consist of wet deposition (acid rain per se, and deposition of acidic fog and snow), or dry deposition of acidic particulate matter, gases, and vapors.

Sources

Acid deposition is largely tied to fossil fuel combustion. In the U.S. approximately 70% of the SO_2 and 30% of the NO_x emissions are produced by electric utility facilities that burn fossil fuels.¹⁰ In most parts of the country, sulfuric acid dominates over nitric acid; however, in southern California nitric acid dominates. Since sulfuric acid has historically dominated, most effort at acid deposition control have focused on SO_2 abatement. In the last few years, the importance of nitric acid has been increasingly recognized; not because of any increases of nitric acid, but rather because of SO_2 controls.

The goal of the EPA's Acid Rain Program (Title IV of the 1990 Clean Air Act Amendments) is to reduce emissions of SO_2 and NO_x . Phase I began in 1996 and affected the SO_2 emissions from 431 electric utility boilers. Phase I also seeks to control the NO_x emissions from 239 coal fired electric utility boilers. Phase II will begin in the year 2000 and will further control emissions from the Phase I units and additional, smaller units also. Besides reducing acid deposition precursors, the Acid Rain Program will decrease levels of sulfates, nitrates, ozone, and improve visibility.

Figure 202.15 shows an overview of the major pathways for acid deposition.

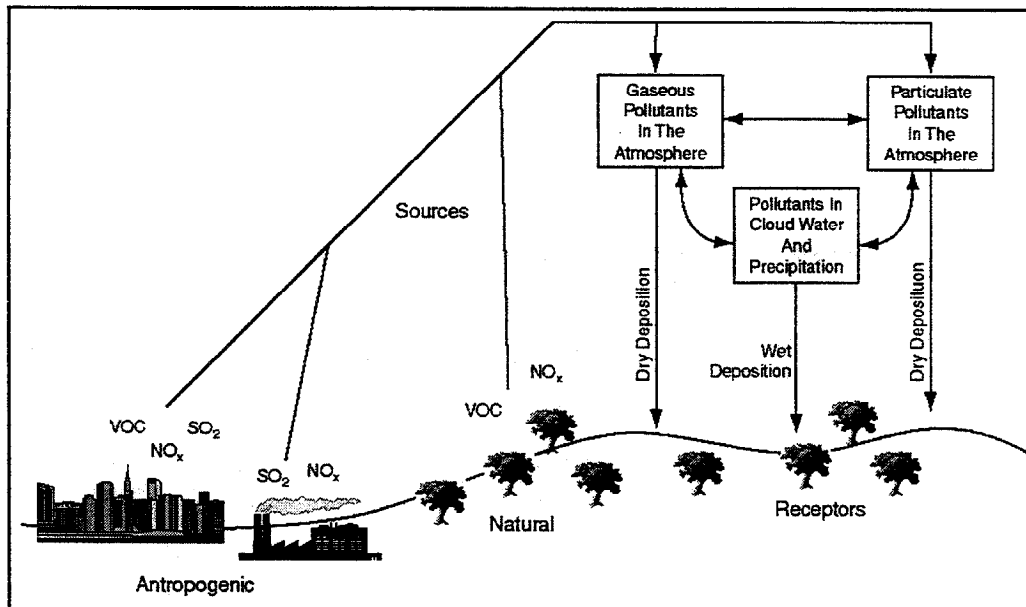
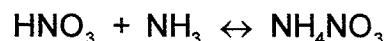


Figure 202.15 Processes Involved in Acid Deposition

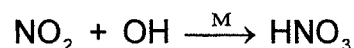
Chemistry of Formation and Reactions

With respect to acid rain formation, the chemistry of NO_x is better understood than that of SO₂. Once formed, nitric acid can be destroyed by photolysis, although this destruction is generally insignificant. Nitric acid can also be removed by neutralization by gaseous ammonia, or in solution by ammonium



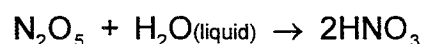
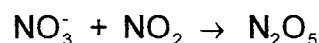
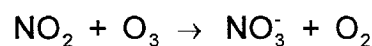
ion. In some areas ammonium nitrate is a significant fraction of the particulate matter.

Nitric acid is formed through two principal reactions.¹⁸ During the day it is formed by the reaction of NO₂ with the hydroxyl radical:



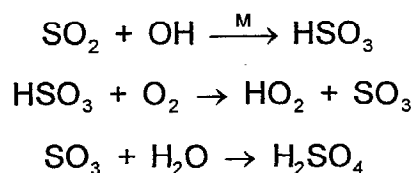
This reaction produces acid; however, it also has the positive effect of removing NO₂ from the ozone formation cycle.

At night, nitric acid is formed by the following set of three reactions:



These reactions cannot take place in the daytime because the nitrate ion (NO_3^-) rapidly photolyzes in the sunlight.

Sulfuric acid accounts for approximately 70% of the acid rain across the country. The exact reaction to form sulfuric acid from SO_2 are not as well documented as the nitric acid formation reactions. To the best of scientific knowledge, the following three reactions account for most gaseous formation of sulfuric acid:



Sulfuric acid is also formed in aqueous phase reactions in cloud water droplets, rain drops, and fog droplets. The aqueous reactions can be very complex and depend on the acidity of the droplet, other pollutant components contained in the droplet, and the mass transfer considerations of uptake of SO_2 into the droplet.

The formation of both nitric and sulfuric acids require hydroxyl radicals. At times the competition for hydroxyl radical means that the formation of the acids are interdependent. For example, increased NO_x concentrations may retard the formation of sulfuric acid by depleting the hydroxyl concentrations in the air.

In addition to nitric and sulfuric acids, other acids also contribute to acid deposition, although to a much lesser extent. Research in Southern California has pointed to the formation of hydrochloric acid by reaction of NO_2 or nitric acid with aerosol sodium chloride (i.e. salt contained in sea spray aerosol).

Due to its higher volatility, a relatively large fraction of the nitric acid may exist in the vapor phase. This can complicate ambient monitoring for nitric acid since, without specific sampling techniques, nitric acid aerosols collected on a filter may be lost to volatilization.

Health Effects

Most human health research has concentrated on acid sulfate aerosols. In general, exposure to acidic pollutants can cause decreased lung function and altered mucociliary clearance of the lungs. This may affect the ability of the lungs to clear inhaled particles and infectious organisms. Long term exposure also can lead to the development of chronic bronchitis and morphological changes.

Biological Effects

The deposition of acidic pollutants can result in the acidification of soils, streams, and lakes. This may directly result in the loss of species in the soil or waterway. The acidification can also result in alteration of the mineral nutritional value of the soil and the mobilization of toxic compounds. Some direct impacts of acid deposition to plant leaves has been observed; however, the cuticular surface of the leaf largely protects it. Erosion of the cuticle may become important in some perennial species. This is generally more related to dry deposition, which may remain on the leaf surface for extended times, than wet deposition which largely drips off quickly. This can be important in California in the summers and desert areas where long times may elapse between rains.

Material Effects

Besides the effects on soils discussed above related to biological effects, acidic deposition can cause considerable erosion and weakening of architectural materials. It has been observed that the historic buildings, monuments, and statuary of Europe has suffered more degradation in the past hundred years than in the previous hundreds to even thousands of years. This has been attributed to the deposition of acidic pollutants.

203 SOURCES OF POLLUTANTS

As can be surmised from the preceding discussion of the individual pollutant types, there are a myriad of pollutant sources, ranging from heavy industrial facilities to automotive sources to routine household activities. Nature is also not without its sources of air pollutants, such as volatile organics from pine trees and particulate matter from deserts.

The sources of pollutants and their emission properties are very important in deciding how and where to monitor for those pollutants.

203.1 ANTHROPOGENIC POLLUTANT SOURCES

Anthropogenic pollutant sources are typically related to fuel combustion, solvent usage, and mechanical grinding.

Many pollutants, particularly for stationary sources, are emitted at high temperature and from a elevated emission points (stacks) which facilitates their diffusion and transport.

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Automotive sources emit pollutants at somewhat elevated temperatures; however, their emission point is at ground level. Automotive sources also consist of many small sources spread throughout a wide area.

Solvents are used in many industrial and household applications. They typically are emitted at lower temperatures and via either short stacks or no stacks at all.

203.2 NATURAL POLLUTANT SOURCES

Nature is not free of guilt as a pollutant source. In some ways, the present oxygen rich atmosphere of the earth is a result of natural pollutants, since the oxygen was produced by photosynthetic organisms, before that time the atmosphere had little free oxygen. Rarely do natural pollutants approach the concentrations produced by anthropogenic activities. Often too, anthropogenic activities may stimulate natural pollutant emission processes.

Natural sources include: forests (volatile organic compounds), microbes (methane and reduced compounds such as H_2S and CO), forest fires (fine particulate, VOC, and NO_x), wind (particulate matter, i.e. blowing dust from deserts, etc.), ocean wave action (particulate matter, especially salt and sulfate aerosol), and incursions of stratospheric ozone carried by down loops of the jet stream (seen at high elevations such as Lake Tahoe).

204 SINKS OF POLLUTANTS

Pollutants are removed from the atmosphere via wet and dry deposition and transformation. As may be expected, these processes are not independent. Moisture may condense onto a dry particle to form a droplet, or evaporate from a droplet to form a dry particle. Gases also are adsorbed and desorbed onto/from particles and droplets. At each stage, chemical reactions can transform the pollutants; sometimes reversibly, sometimes irreversibly.

The processes involved in removing pollutants from the atmosphere is important in siting a monitoring station and monitoring for the proper pollutant species. If deposition or transformation has removed the primary pollutant, monitoring for that pollutant at that site may be pointless, perhaps another site should be chosen or the secondary pollutant monitored. Understanding the pollutant removal properties of trees, etc. is also important.

By the time a particle or droplet is deposited it represents the history of the airmass from which it is deposited. As the airmass is transported inputs of pollutants, deposition outputs, and mixing continually alter wet and dry deposition processes and species. Once deposited, pollutants are not necessarily permanently removed from the atmosphere. For example: wind may resuspend particulates, or additional chemical reactions once the pollutant has been deposited may convert it into a form that can be returned to the atmosphere.

204.1 WET DEPOSITION

Deposition of pollutants can be divided into two major categories: dry and wet deposition. In wet deposition particles and gases may be scavenged by diffusion to droplet surfaces or serving as nucleation sites for raindrops (rainout) and by interception by falling rain and snow (washout).

204.2 DRY DEPOSITION

Dry deposition is the removal of pollutants by the impaction, interception, settling, and diffusion of particulate matter and gases without being part of a water drop. Dry deposition can be approximated by the sum of the resistances to deposition (Figure 204.1). The lower the resistance, the greater the chance that the pollutant will be deposited. Diffusion is an important mechanism for particle transport and deposition for particles less than $0.1 \mu\text{m}$ over short distances. Where the physical scale is larger, convection is more important.

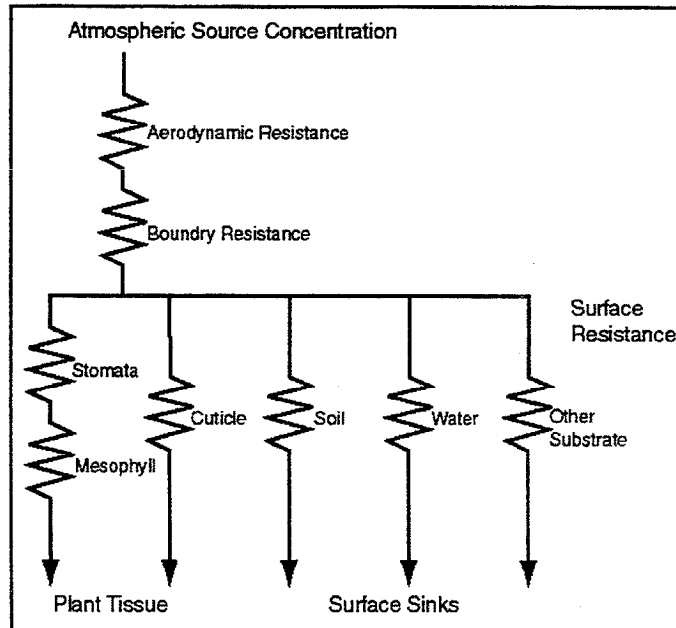


Figure 204.1 Dry Deposition Resistances

Dry deposition rates are approximated in terms of their deposition velocity (V_{dep}). Deposition velocity is defined as the deposition flux divided by the

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undisturbed concentration.⁸ It is the effective velocity with which particles and gases migrate to a surface.

$$V_{\text{dep}} = \frac{J}{n_0} = \frac{\text{number deposited} / \text{cm}^2 \times \text{s}}{\text{number} / \text{cm}^3} = \text{cm} / \text{s}$$

Particles larger than approximately 100 μm tend to free fall through the atmosphere so rapidly that their diffusion and dispersion is negligible. Particles between 20 and 100 μm will migrate downward and eventually deposit to the ground. Those particles between 0.2 and 20 μm deposit by settling only slowly and can usually be treated as gases for dispersion purposes. Finally, the particles less than 0.2 μm often remain airborne for extended periods of time.¹⁸ However, particles in the nucleation or ultrafine size range ($\sim 0.08 \mu\text{m}$, particles directly emitted from a combustion source or condensed shortly after emission) have typical lifetimes of less than one hour in the atmosphere because they rapidly coagulate with other particles or serve as nuclei for cloud or fog droplets.

Dry deposition is especially important in California since there is little rain in the summer months. The deposited pollutants remain on the surface they were deposited on for extended periods of time, allowing the acidity, etc. deposited to have maximal effects. In California, when the first rains of the fall and winter occur, the pollutants may be rinsed from the leaves etc. and enter the streams, lakes, and rivers in a large pulse.

204.3 REMOVAL BY TRANSFORMATION

Pollutants may also be removed from the atmosphere through chemical or physical transformation. Although the pollutant may be removed in its original form, the product of the reaction or physical process may be as harmful as the original compound, or even more harmful.

Many of the transformations that pollutants undergo were discussed in the preceding sections about each pollutant. Examples of transformations are the conversion of NO_x and SO_2 emissions into their acids (HNO_3 and H_2SO_4) and their subsequent conversion into particulate matter, largely as particles containing NH_4NO_3 and $(\text{NH}_4)_2\text{SO}_4$. The nitrate bearing particulate is prone to decompose, re-releasing the nitric acid into the atmosphere, requiring care when monitoring.

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Ambient Air Monitoring

205 RELATIONSHIPS TO EMISSION SOURCES

The ambient concentrations of pollutants measured at monitoring stations are related to the emission sources; however, the relationships often are quite complex. By the time pollutants reach a monitoring station, they may have been converted to secondary pollutants, chemically transformed in some manner, or selectively removed from the air mass. For example, unusual bulges and deficits in ozone concentrations have been observed when power plant emissions are interjected into an air mass.⁵⁰ The bulges and deficits occur as the concentrations and ratios of NO_x and hydrocarbons are changed.

Whether an emission source will impact a particular monitoring station will depend on the weather, topography, and other transport functions in addition to the atmospheric chemistry during transport. Ideally, computer models should be able to predict these relationships. In practice, inaccuracies, approximations, etc. of the models and the emission inventory preclude precise predictions. Although combining the models, meteorological observations, and a detailed analysis of the pollutants measured (over time and space) can generally provide sufficient information about the source/receptor relationships for enforcement, regulation development, etc. by the air quality agency.

Controlling secondary pollutants requires knowing the primary pollutants and transformations involved. Ozone is an important example. Ozone is one of the most important air pollutants in California; however, no sources emit it. It is strictly a secondary pollutant. How then do we control ozone; we control the primary pollutants. This requires knowledge of the atmospheric chemistry that created the ozone we need to control and the transport that got it to the monitoring station. (Alternatively, if we suspect an ozone problem to exist we need to know these same things to know where to locate the monitoring station to track the progress of our control efforts.) Principally by controlling the emission of NO_x and hydrocarbon precursors we can control the downwind ozone concentrations. Fine particulate matter and visibility reductions are also important secondary pollutant classes that must be controlled by controlling the primary pollutant emissions.

206 CHEMISTRY

Atmospheric chemistry is extremely complex. Each year many doctoral dissertations, scientific journal articles, and books are written about the subject. Still,

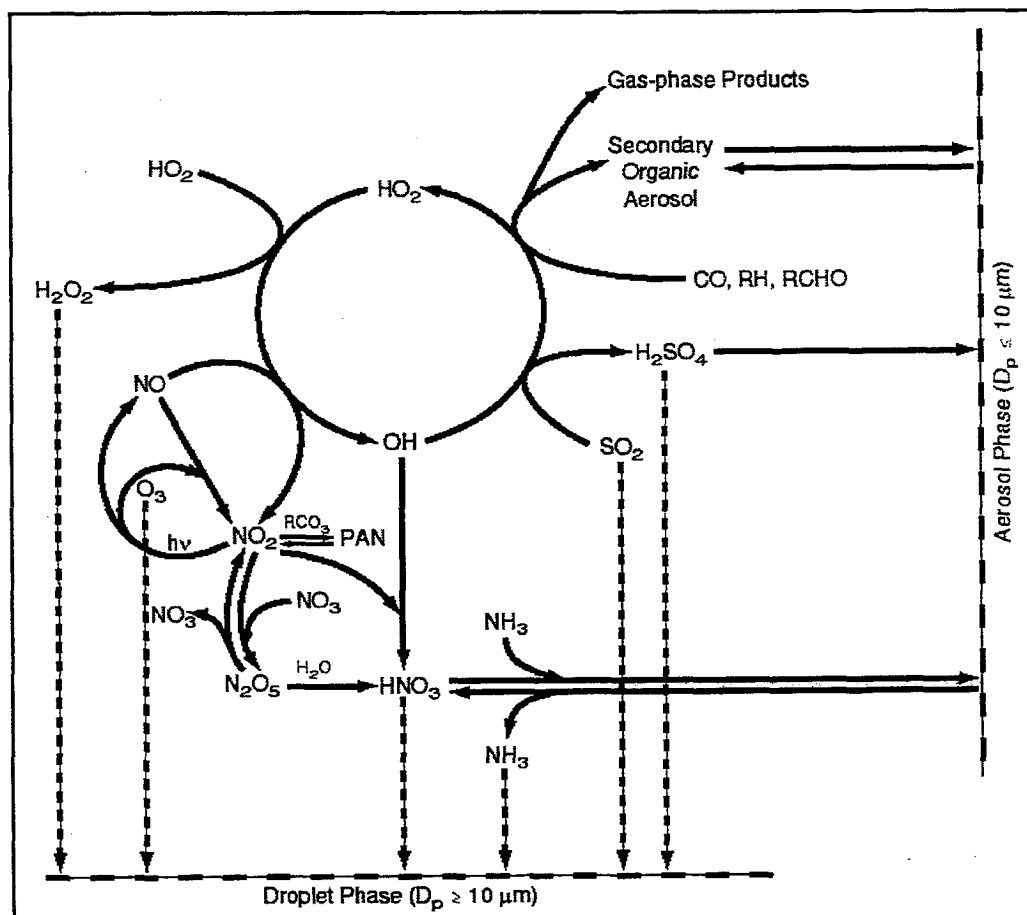
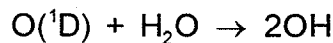
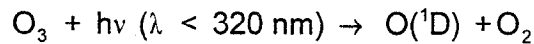


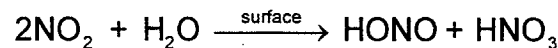
Figure 206.1 Chemical coupling of atmospheric gas, particle, and droplet phases and the hydroxyl radical.⁵⁰

much remains to be learned. In the preceding sections concerning each pollutant, a summary of the chemistry of that pollutant was presented. In reality, the chemistry of each pollutant cannot be looked at individually, the entire complex of atmospheric chemistry operates as a whole system.

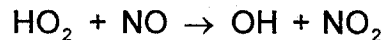
If there is any unifying feature to atmospheric chemistry it would be the chemistry of the hydroxyl radical (Figure 206.1). The hydroxyl radical plays a central role in atmospheric chemistry because of its high reactivity with organic as well as inorganic compounds.⁷ In many of the preceding discussions of the individual pollutants, the hydroxyl radical is noted as important in the chemistry of the pollutant. Major sources of hydroxyl radicals include: the photolysis of ozone and subsequent reaction of the excited oxygen with water molecules to form hydroxyl,



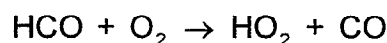
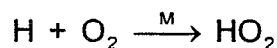
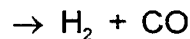
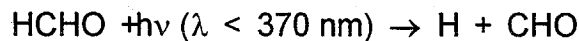
photolysis of nitrous acid (HONO),



the reaction of HO_2 with NO ,



and the photolysis of organic compounds such as formaldehyde.



Since OH is the major atmospheric sink for most pollutant gases, their residence times are largely determined by their reactivity with OH and by its spatiotemporal distribution. The overall effect of OH is to act as "the detergent of the atmosphere."⁶

Ammonia is also an important factor in atmospheric chemistry.^{39,51} In particular, it provides a means of forming particulate phase nitrogen and sulfur oxides. Ammonia emissions are almost exclusively associated with agricultural operations, especially intensive livestock feedlots.

207 POLLUTANT TRANSPORT

Pollutants may be imported into an area from possibly distant area or exported to other regions through advective transport. Fine particulate matter and gases have been known to be transported from China to the northwest United States and from the Sahara Desert to the Virgin Island and southeast U.S. Those pollutants transported a very long distance are interesting from a research standpoint, but at the receptor they are typically very diffuse. From a more practical viewpoint, transport distances of a few kilometers to a few hundred kilometers is much more important for ambient monitoring decisions.

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Transported pollutants can have economic as well as ecological impacts. Summer visitation has declined in recent years in several eastern U.S. national parks (Shenandoah and Great Smoky Mountains) partly in response to transported particulate matter forming hazes which impair visibility;⁵⁴ tourists literally can't see very much, so they don't come.

As was discussed above, in the section on chemistry, mixing of pollutants from several regions can have significant impacts on the atmospheric chemistry. Transport also corresponds with time for atmospheric chemistry to modify primary pollutants and form secondary pollutants. The best example of this is that the highest ozone concentrations are typically a few kilometers downwind of the primary pollutant source area. As the air mass moves away from the source area, the ratio of NMHC to NO_x increases due to the shorter lifetime of NO_x . For example, as an air parcel moves away from the city of Toronto it has been shown that the ratio of NMHC to NO_x increases and the potential photochemical production of ozone increases.⁴²

The locations the monitoring stations of the Photochemical Assessment Monitoring Stations (PAMS) network specifically take transport and transformations into account.

207.1 WEATHER AND CLIMATE

Apart from the topography, the weather and climate have the most profound influence on pollutant transport. The weather has a significant influence on atmospheric chemistry and pollutant transport. Regional climate (seasons of the year, average temperature, average rainfall, etc.) is the summation of the weather conditions of a location. As such, climate is the more important variable to consider when seeking a location to establish a monitoring station and in projecting pollutant transport.

Weather fronts can be very effective in carrying pollutants from one region into another. On June 24, 1985, during the Sequoia Study,⁵² a well developed trough in the western U.S. caused the advection of a high sulfur air mass from the oil fields of the southern San Joaquin Valley into the Sequoia National Park (Figure 207.1).

During the 1987 Sequoia Study a storm also crossed the Sierra Nevada from the east. This storm left a definite signature on the particulate concentrations and composition. Before reaching the Sierra Nevada the storm had passed through

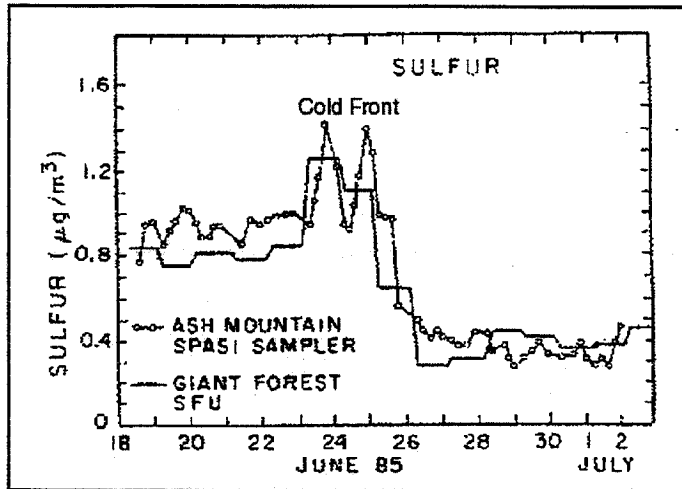


Figure 207.1 Effect of a Frontal Passage on Sulfur Concentrations in Sequoia National Park⁵¹

Arizona, where it picked up heavy metal containing particulate. As the storm passed the monitoring station at Emerald Lake, the particulate collected contained a sudden and short duration peak of those metals.

Meteorology is often closely coupled with the topography of the region. Wind patterns are often complex in rugged (i.e. mountain-

ous) regions. Pilot balloon studies by Ewell et. al.⁵³ revealed three wind regimes in the Sequoia National Park area. The first, lower, boundary layer flows are dominated by regular oscillation of upslope and downslope winds controlled by the valleys and mountain slopes and the diurnal heating.

The second meteorological regime is the mesoscale San Joaquin Valley wind system. This circulation sweeps up the valley in a southeasterly current which reaches its maximum strength in the late evening. There are two significant features of the San Joaquin Valley circulation that bear on pollutant transport into Sequoia National Park: the nocturnal jet and the Fresno eddy. The nocturnal jet results from the night time inversion and reaches its strongest about midnight. The jet transports pollution from central California to the southern San Joaquin area.

The Fresno eddy is a swirl of air west of Visalia on the eastern side of the valley that causes a funneling of the northwesterly morning flow to the west part of the valley. The eddy is a mechanism by which pollution from the oil fields at the southern end of the valley are transported to the central region.

The third regime is associated with synoptic-scale variation. These fluctuations control long-range transport, particularly that associated with meteorological events. The sulfur event discussed above (Figure 207.1) is an example of synoptic-scale transport.

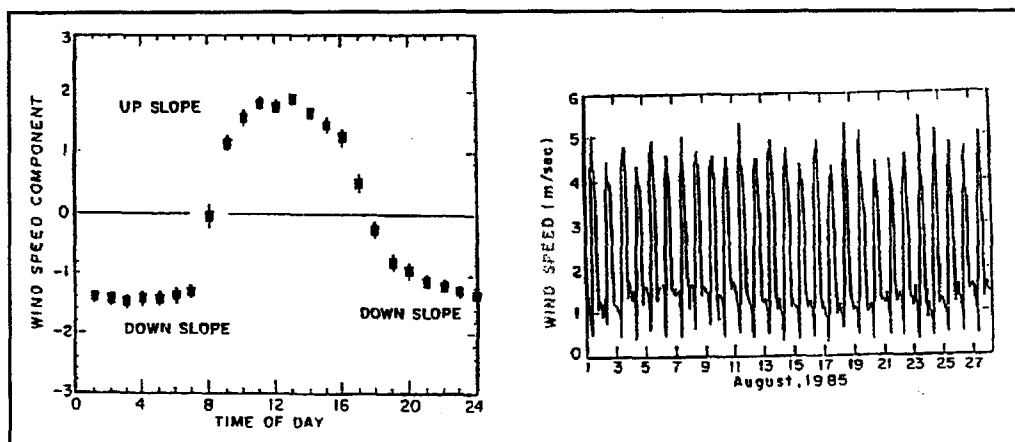


Figure 207.2 Mean Diurnal and Hourly Speeds of Terrain Driven Winds at Sequoia National Park^{51,55}

207.2 TOPOGRAPHY

As mentioned above, topography is the second major factor determining transport. In areas that are largely flat (i.e. plains) meteorological influences dominate. However, in mountainous areas, such as California, topography is the predominant factor.

In mountainous areas ozone and fine particulate exposures and transport are largely controlled by terrain rather than region-wide winds.⁵⁵ The terrain winds channel the pollutants up valleys. In addition, heating during the day causes the air mass to be transported to higher elevations deeper in the valleys. In these areas settlement patterns, terrain, and transport may be conducive to the formation of localized hot spots of high pollutant concentrations where pollutants concentrations converge by transport.

It has long been observed that daytime heating and nighttime cooling produce upslope and downslope (respectively) winds in mountain/valley topography. In the Sequoia Study, regular upslope and downslope winds were observed as expected (Figure 207.2). Analysis the spacial and temporal patterns of ozone and particulate matter concentrations, sizes, and composition in Sequoia National Park are consistent with the winds, demonstrating transport into the park.⁵⁶

Figure 207.3 shows the diurnal variations of ozone in Sequoia National Park from Visalia on the valley floor into Sequoia National Park, including Ash Mountain at 670 m (2,200 ft), Giant Forest at 1,800 m (6,000 ft) and Emerald

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Lake at almost 3,000 m (10,000 ft). The similarity of the peak concentrations at Visalia, Ash Mountain and Giant Forest (including temporal variability not shown) and the delay in the peak concentrations at the higher elevation sites that coincides with the diurnal terrain winds indicates transport into the park. The transport is much attenuated at Emerald Lake.

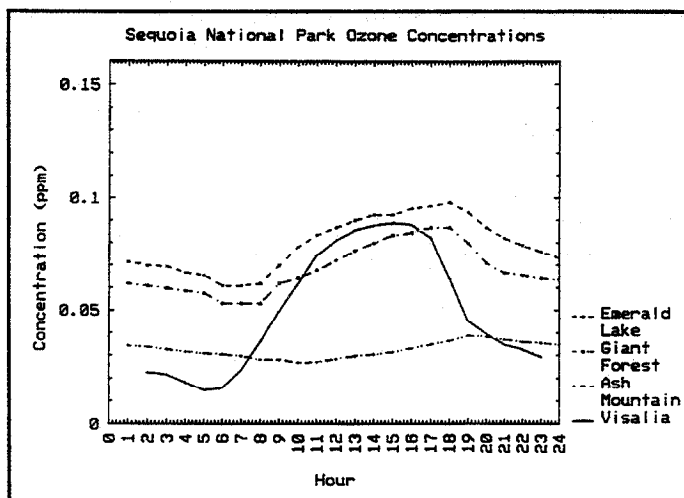


Figure 207.3 Ozone Concentrations by Elevation in Sequoia National Park⁵¹

The ozone curves at Sequoia National Park (Figure 207.3) also show another common feature of ozone transport in mountainous areas. The nighttime concentrations at Visalia are quite low, often reaching zero, reflecting scavenging. The high elevation sites are mixed with clean air, with minimal scavenging potential, during downslope nighttime transport and remain at relatively high levels.

207.3 URBAN AREAS

Urban areas are the primary source areas of transported pollutants. During transport atmospheric chemistry may significantly alter the pollutant components and concentrations in the air mass. The most important example is ozone; which is formed in the air mass as it is transported. The greatest concentration of ozone is usually some distance downwind of the urban area. The PAMS network is designed to monitor this phenomenon.

Particulate matter changes significantly as it is transported. Gases can be condensed or adsorbed onto the particles, vaporized from the particles, or participate in reactions on the particles. There is also a segregation process as the air mass is transported with the larger particles being deposited. At a distance the particles in the air mass are dominated by fine and secondary particles.

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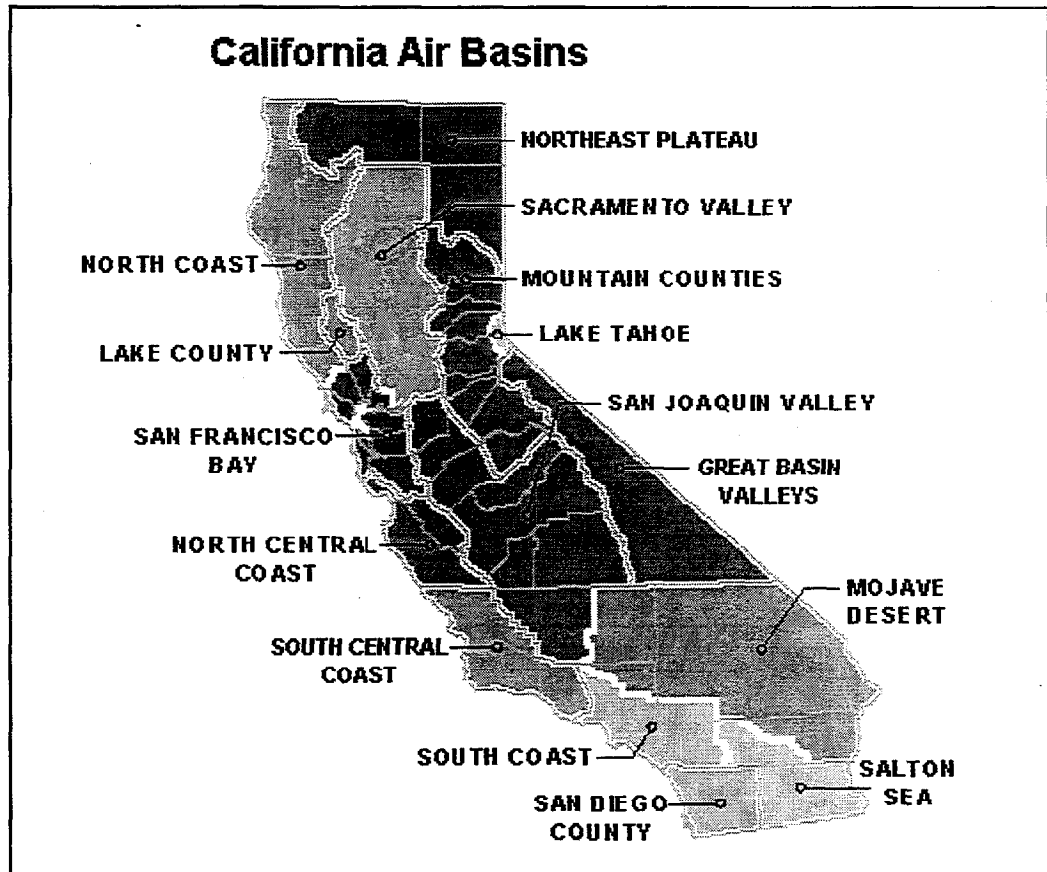


Figure 207.4 Map of Air Basins in California

207.4 CALIFORNIA AIR BASINS

Air basins can be compared with river watersheds; they constitute the basic volume in which the air mass has to mix and transport, although the air mass can be transported across mountain passes into neighboring air basins. Since California has a number of mountain ranges and valleys, air pollution dispersion and transport is defined and constrained by more discrete air basins than most states. The state has been divided into 15 air basins (Figure 207.4 and Table 207.1). Most of the air basins extend beyond the boundaries of a single county. In many instances also, counties are divided between two (or more) air basins.

In both the San Joaquin and Sacramento Valleys an inflow of air off the Pacific Ocean forms rotating gyres that contribute to mixing and transport of pollutants. As was discussed in section 207.1, the San Joaquin Valley gyre can effectively transport pollutants from the Bay Area and northern San Joaquin Valley well

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Table 207.1 California Air Basins and Counties

| Air Basin | Counties |
|------------------------|---|
| Great Basin Valleys | Alpine, Inyo, Mono |
| Lake County | Lake |
| Lake Tahoe | El Dorado, Placer |
| Mojave Desert | Kern, Los Angeles, Riverside, San Bernardino |
| Mountain Counties | Amador, Calaveras, El Dorado, Mariposa, Nevada, Placer, Plumas, Sierra, Tuolumne |
| North Central Coast | Monterey, San Benito, Santa Cruz |
| North Coast | Del Norte, Humboldt, Mendocino, Sonoma, Trinity |
| Northeast Plateau | Lassen, Modoc, Siskiyou |
| Sacramento Valley | Butte, Colusa, Glenn, Placer, Sacramento, Shasta, Solano, Sutter, Tehama, Yolo, Yuba |
| Salton Sea | Imperial, Riverside |
| San Diego | San Diego |
| San Francisco Bay Area | Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano, Sonoma |
| San Joaquin Valley | Fresno, Kern, Kings, Madera, Merced, San Joaquin, Stanislaus, Tulare |
| South Central Coast | San Luis Obispo, Santa Barbara, Ventura |
| South Coast | Los Angeles, Orange, Riverside, San Bernardino |

down the valley and into the southern and central Sierra Nevada. A similar gyre occurs in the Sacramento River Valley. The Sacramento gyre transports pollutants from the Bay Area and City of Sacramento area into the northern Sacramento River valley. It also is responsible for pollutants reaching the cities of Woodland and Davis from unusual directions, i.e. from the northwest, a direction in which there are no sources.

208 EFFECTS

Air pollution effects have traditionally been divided into health effects and welfare effects. As would be expected, this vastly simplifies the very complex set of interactions and effects of pollutants. Specific information concerning the effects of each pollutant have been covered in the previous sections about the pollutant properties. However, air pollutants rarely manifest their effects singly, often the effects are synergistic, exacerbating the health and welfare impacts.

Health effects may be immediately life threatening at low concentrations to of health concern only after long exposure or exposure to high concentrations. Such effects as global climate change have typically been classified as welfare effects; however, secondary effects such as heat extremes and disease spread expected from a warming climate may also have health effects indirectly attributable to the pollutant.

Welfare effects cover a wide variety of effects. These effects can be divided into materials effects, agricultural and ecological effects, and visibility impacts and effects.

208.1 HEALTH EFFECTS

Air pollutants can cause a number of health effects, including chronic respiratory diseases, acute respiratory symptoms, and aggravation of asthma symptoms, resulting in restrictions of physical activity, increased hospital admissions, and increased premature mortality.

The most common and potent route of exposure to air pollutants is through inhalation. Pollutant-induced airway toxicity may be characterized as i) oxidant and irritant gases; ii) particulate (including bulk); iii) reactive aldehydes; and iv) heavy metals.⁵⁷ Sustained exposure of sensitive epithelial or mucosal sites may lead to mucosal irritation and thus predisposes the airway to hyperreactivity and further impairment of mucociliary clearance.

The lungs, a natural gas exchange organ, provide near direct contact between inhaled gases and the blood stream, and, therefore, efficient absorption of the pollutants into the body. In addition, the interior of the lungs provides the moisture into which hygroscopic gases and particles can dissolve. Once in solution the pollutants can injure epithelial cells and rapidly move into the body. Alternatively, pollutants may cause changes in active ion transport, composition

or osmolarity of the periciliary fluid layer and thus cause swelling and changes in permeability.

Fine particles are especially efficient at bringing pollutants into deep lung tissues. For example, diesel exhaust particles may bring toxic substances such as benzene, formaldehyde, 1,3-butadiene, arsenic, and nickel (among other cytotoxic, mutagenic, carcinogenic, and teratogenic compounds) into contact with the permeable alveolar linings.

Pollutants that are otherwise chemically inert may physically block the lungs, reducing their air exchange capability. They may also physically irritate the lungs, causing inflammation, swelling, and restricted respiratory function.

Acute exposure to pollutants may result in localized cellular response (i.e. mucus secretion, blood flow, and transudation of fluid into the airways). Longer-term irritation or mechanical injury commonly causes damage to the bronchial epithelium and impairment of clearance. For example, short-term exposure to 5 ppm SO₂ increases mucociliary clearance while chronic exposure to 1 ppm SO₂ causes impaired mucociliary activity as an early sign of pulmonary disfunction; probably as a result of loss of ciliated cells and altered mucus secretion.

208.2 WELFARE EFFECTS

Welfare effects can be seen as a catch-all type of classification; if a pollutant has effects, but those effects do not directly effect people's health, then the effects can be classified as affecting the general environment or a person's enjoyment or use of the environment. Welfare effects can be divided into materials effects (i.e. corrosion of metals, rubber, and building materials, etc.), effects on biological systems (i.e. agricultural and ecological effects), and visibility impairment.

208.2.1 Materials Effects

The damage to materials by air pollutants is not a single cause and effect process. In addition to interactions between the pollutants, many natural factors strongly influence those effects. Since the natural processes may exhibit similar damage to materials, it is often difficult to determine the incremental damage from air pollution. Pollutants may also act synergistically with the natural environmental factors to increase damage beyond that that would be seen due to either alone, which complicates the analysis even more. Air pollutants may

cause damage through five principal mechanisms,^{58,59} the means of action of a specific pollutant were discussed in the previous section about the individual pollutants (Section 202).

Abrasion

Solid particles of sufficient size and velocity can cause destructive abrasion. Large, sharp edged particles can embed in fabrics and accelerate wear.

Direct chemical attack

Some air pollutants react directly and irreversibly with material surfaces; for example, the reaction of acid gases with carbonate building stone can cause leaching and spalling of the stone.

Indirect chemical attack

Materials may absorb pollutants, which can undergo chemical reaction with the material (or some chemical in the material). The converted pollutant then may attack the material. An example of this mechanism is the absorption of SO₂ by leather, conversion of the SO₂ into sulfuric acid by chemical residues in the leather, and the subsequent weakening of the leather by attack by the sulfuric acid.

Corrosion

Corrosion is an electrochemical interaction with the atmosphere or pollutants. It occurs in the natural atmosphere even in the absence of pollutants. However, the presence of pollutants greatly increases the rate of corrosion. Rust of ferrous metals (i.e. iron) is a prime example. Numerous very small (on the order of tens to hundreds of micrometers in size) electrochemical cells form on the metal surfaces exposed to the atmosphere. The plus and minus electrodes of the cell result from microscopic chemical or physical differences on the metal surface. The difference in the electric potential between these areas is the driving force for the corrosive action. In effect, the result of the corrosive actions is that the metal dissolves away like the plates of a short circuited battery. Water, even a molecular layer on the surface is necessary for the action to take place. If the water contains air pollutants, resistance is lowered and the electrons can flow more readily. Some hygroscopic air pollutants, such as H₂SO₄, can attract water from the air, increasing the corrosive action.

Another corrosive mechanism involves the removal of protective layers. In dry air iron develops a protective film which insulates it from atmospheric assault. When SO₂ is present, this layer can be broken down, exposing the surface to

corrosive oxidation. Iron is often galvanized (plated with zinc) to provide an additional protective layer. With metals like zinc CO_2 in the atmosphere forms a protective carbonate layer. Acid pollutants, such as H_2SO_4 , dissolve away this carbonate layer, and eventually the zinc itself, to expose the underlying iron to corrosion.

Deposition and Removal of Particles

The deposition and removal of particles may include effects of abrasion and corrosion: accelerating the corrosion of the surface beneath them, abrading the surface (during deposition, flexing of the material, and removal of the particle), and discoloration of the surface. While discoloration may be less directly damaging, impacting the appearance only, it is often an important part of the function of fabrics and painted surfaces. Unintended changes in the appearance can affect the uses to which a material can be put. It also can have safety implications in the soiling and fading of safety and highway signs. Efforts to clean surfaces also frequently result in damage and shortened useful life.

Particles can also act as concentrators of other pollutants. For example, acid gases, hydrocarbons, toxic compounds, etc. may be adsorbed onto particles and carried to a surface where they remain until they react or are cleaned away, rather than being able to diffuse away by simple diffusion. Particles can also penetrate deeply into the lungs and bring their adsorbed pollutants into strong and persistent contact with the cells lining the lung. Damage may also appear as localized spots around the particles. This mottling may be more visible than damage spread evenly over the whole surface.

The damage observed on materials cannot be solely attributed to air pollutants. Many natural factors can also damage materials, often in ways nearly identical to the damage by pollutants. These natural factors may act as enabling mechanisms, act along side the pollutant impacts, or they may act synergistically.

Moisture

Moisture is an essential ingredient in the formation of corrosion. Without moisture, corrosion from even the most severely polluted atmosphere would be nearly nonexistent. Although visibly wetted surfaces are not required. Realistically, the atmosphere on Earth contains enough moisture in all but the most arid locations to maintain at least the needed molecular layer of moisture. Moisture in the form of rain often reduces corrosion rates. The large amount of moisture associated with rainfall will dilute the pollutants on the surface and wash away the accumulation of pollutants. Under some conditions, light rainfall will cause

high concentrations of the corrosive agents along the lower edge of an object (where droplets accumulate prior to dripping off).

Studies of the joint effect of humidity and SO_2 in producing corrosion in iron have shown that even for high pollutant concentrations, corrosion was minimal at relative humidities below 60%. As the humidity was increased to 80%, corrosion rapidly increased.

Particles

Some natural particles, such as sea salt aerosol, are electrolytes and can greatly increase corrosion of metals in moist atmospheres. Other particles, such as soot and charcoal particles, can adsorb pollutants on their surface and concentrate them. These particles may accelerate corrosion by bringing those chemicals into prolonged contact with the metal surface. Carbonate bearing particles (i.e. limestone rock dust, etc.) can reduce the effect of acid vapors and gases by neutralizing them.

Temperature

Objects exposed to cool, clear, calm nights lose heat rapidly through radiative cooling. If exposed to a clear sky they can rapidly cool to temperatures below the ambient temperature. If the temperature falls below the dew point, moisture (dew) will condense on the surface. As has been previously discussed, this increase in surface moisture can accelerate corrosion.

Table 208.1 lists some specific materials, damage types, and remediation / prevention methods. This table illustrates some of the costs that can be associated with material damage by air pollutants. These costs can be aggregated into three general categories:

Direct Costs

The most obvious costs associated with material damage due to air pollutants are for repair or premature replacement. Important functions of repair costs are the effectiveness of the repair in restoring complete functionality, the ratio of materials to labor costs (since repair is often labor intensive), economic lifetime, and physical lifetime. In some cases general wear outweighs the effects of air pollutants. In which case the costs of air pollution may be minimal, in spite of the fact that significant damage is being inflicted. This is generally the case with automobiles, whose economic and physical lifetime is more related to miles driven and highway conditions than pollutants (although air pollution may shorten the lifetime of rubber items such as windshield wipers, seals, and tires).

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Table 208.1 Air Pollution Damage to Materials⁵⁷

| Materials | Type of Damage | Typical Cost Manifestations |
|--|--|---|
| Metals | Corrosion or tarnishing of surface Spoilage of appearance | Cleaning, surface coating, plating, and early replacement |
| | Loss of metal Loss of strength | Early replacement Use of more expensive alloys or surface coating of replacement |
| Building Materials (Stone and Concrete) | Discoloration | Cleaning and repainting |
| | Spalling and leaching | Surface treatment, sandblasting, and repointing |
| Paint | Chemical discoloration | Repainting with non-reactive paint |
| | Soiling | Cleaning and more frequent repainting |
| | Increased drying time (Dried coating is softer) | Repainting at time of low ambient pollution levels |
| | Reduced flexibility Reduced gloss Pitting | Early repainting |
| Textiles | Weaking | Early replacement |
| | Soiling | More frequent cleaning and earlier replacement |
| Dyes | Fading and color change | Earlier replacement |
| Elastomers | Cracking and weakening | Replacement |
| Leather | Weakening | Replacement Use of special environment (Libraries and museums) |
| | | Surface treatment |
| Paper | Embrittlement | Special chemical treatment Use of special environment Replacement |
| Ceramics | Changed surface appearance | Increased cleaning Replacement |
| Electrical Contacts | Corrosion | Plating with precious metals |
| | Increased contact resistance | Early replacement |
| Electrical Insulators | Shorting through conducting path created by particulates | Washing Replacement when insulator fails |
| Works of Art | Soiling, corrosion, spalling, etc. | Use of special environment Replacement with duplicate (original kept in special environment) Application of protective coatings |

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Avoidance

The use of protective measures offers a degree of avoidance of the direct costs of repair and replacement. The principle protective measure employed is the use of coatings; i.e. galvanizing and painting. The effects of air pollutants on materials can also be avoided by using alternative materials that are more resistant. The alternative materials may be more expensive, less durable in other ways, or aesthetically less pleasing, but serve the original purpose and avoid damage from air pollutants.

It should be noted that coatings may not provide complete protection from damage. Small defects, such as pin-holes or thin spots and areas subject to wear, can leave areas unprotected. Damage may begin through one of these small defects and spread behind the coating, causing significant unseen damage before being detected.

Aesthetic

Air pollution can soil, fade, or discolor surfaces. The resulting "unsightly" surface may then require premature repainting to restore an aesthetically pleasing appearance.

208.2.2 Agricultural and Ecological Effects

Biological effects, other than human health effects, can be an important aspect of air pollutant exposure. These effects are given secondary billing as "Welfare Effects" and almost universally less stringent standards: however, in the long run, agricultural and ecological effects will have significant effects on human health and well-being. Agricultural and ecological effects are closely related, except that the biological systems being impacted as an agricultural effect are those that are being cultivated and the ecological effects occur in uncultivated systems.

Ozone and acid deposition are the most studied agricultural and ecological effects; however, by no means the only effects. In the previous sections about the properties of each pollutant, the effects of each were discussed.

It has been calculated⁶⁰ that reducing ozone concentrations to 0.025 ppm would result in a benefit of approximately \$1.5 billion (1990 dollars) and an increase in harvest by over 22%. A less stringent reduction, to 0.09 ppm (the California state standard) would result in a benefit of \$213 million (1987 dollars). Clearly,

agricultural impacts of ozone are significant; however, achieving those reductions would be very difficult.

Work that this author has personally done in the Sequoia National Park area indicates that virtually every Jeffrey pine tree has been injured by ozone. Metabolically, the injury shows up at very low levels of exposure.²³ While most of the trees are outwardly healthy (although some are visibly injured), reduced carbon fixation capability and increased diversion of carbon resources to maintenance and repair result in reduced vigor and a competitive disadvantage for those plants. Ultimately resulting in possible changes in the ecosystem.

Acid deposition has also been heavily studied. However, since acid deposition has so many different potential effects, it is very difficult to give a consistent picture of its effects. The pH of the deposition is generally the reported quantity. However, unless one also knows the degree to which the deposition is buffered at that pH, the resulting effects cannot be reliably predicted. To determine the ecological effects, it is also important to know the acidic species (i.e. nitric or sulfuric acid). In soils, waterways, etc. the chemistry and resulting effects depends on the chemistry of the depositing pollutants.

208.2.3 Visibility

Visibility is important from an aesthetic point of view and as an indicator of other pollutants in the air. In many national parks extended vistas are the primary attributes of their existence as a park. The general public is, for the most part, not aware of air pollution unless they see a visible haze in the air. Although ozone, toxic compounds, etc. may be of greater health and welfare impact, "out of sight, out of mind" is often the operative phrase.

Fine particles that make up the visible haze carry the signature of the emission source. Analysis of the composition can be an invaluable tool for assessing the cause of the haze and devising control strategies.

208.3 RISK ASSESSMENTS

Risk assessment have been defined as a process that evaluates the likelihood of adverse effects resulting from exposure to one or more stressors. Four factors are necessary for a risk to exist:⁶¹

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- The stressor (pollutant) must have the ability to cause adverse effects;
- The stressor and ecological (species, population, community, or ecosystem) or health component must co-occur;
- Exposure must be for sufficient time to elicit the adverse effects; and
- Exposure must be at sufficient concentration to elicit the adverse effects.

Inevitably, risk assessment involves both policy and science.⁶² Risk assessment lies at the interface of policy and science wherein policy must be used to make management based decisions based on scientifically relevant information. Policy decisions involve the identification and assessment of socially valued ecological components. The targeted ecological components, being socially selected, may not be those that play crucial ecological roles. One of the roles of scientific input is to guide the component selection.

Not all adverse effects are equally important. When multiple risks need to be evaluated simultaneously, each separate risk factor must be normalized so that the normalized score represents the percentage that the factor represents of the entire risk assessment. The adverse effects can be classified into one or more of the following categories, within each of which there may be a number of measurable adverse effects.

- Economic production;
- Ecological structure;
- Genetic resources; and
- Cultural values.

The interplay of policy and science has at times allowed a variety of myths and misconceptions to creep into the analysis process. Significant among these misconceptions, because of their use in managing and/or reducing impacts on the environment are the notions that:

- A "sentinel" or "most sensitive" species can be chosen and reliably used for environmental protection.

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- Chronic toxicity data are superior to acute data for regulatory purposes.
- Controlled experimental data can be accurately extrapolated to predict the nature and magnitude of population, community, and ecosystem level responses to known stresses.
- Ecosystems are uniformly sensitive to different stresses.
- Data from time limited tests can be used to assess long term responses.
- Reductions in ecosystem complexity imply increasing system instability and impending catastrophe.
- "Good science" will remedy any and all environmental problems.

The crux of resolving these misconceptions and myths is to understand that the ecosystem is spatially and temporally complex. The heterogeneity of biological, climatological, and edaphic conditions is a constant and dynamic interplay of interdigitating patches. The interaction of each combination of these factors with pollutant stresses may result in a different endpoint risk.

None the less, risk assessment is a valuable tool for the evaluation of environmental effects of air pollutants. Ambient monitoring data is one of the prime inputs in the risk assessment analysis. However, care must be used in interpreting what the ambient data are saying about the pollutant exposures.

209 INFLUENCE OF SAMPLING PROTOCOL

From the above discussion of risk assessments, it should be obvious that the sampling procedures and protocols will have a great impact on establishing an air monitoring program.

209.1 SPATIAL COVERAGE

As has been discussed in previous sections of this manual, pollutant concentrations are not spatially uniform. Especially in areas with extensive topography, the location and configuration of an air monitoring station can have very important influences on the area over which the results from that station are representative. Section 603 in this manual contains a discussion of air monitoring station scales.

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Spatial coverage also entails making the most of one's air monitoring budget. It would be both fiscally and physically impossible to completely cover an area with monitoring stations. By carefully choosing station sites, the data can be extrapolated to estimate pollutant concentrations throughout an area of interest. In establishing an air monitoring network consideration must be given to geographic factors (mountains, valleys, coastal areas etc.), climatological factors (wind speeds and directions, temperatures, etc.), pollutant sources (both local sources and transported sources), and population centers when selecting the monitoring station location.

209.2 FREQUENCY OF SAMPLING AND TIME AVERAGES

Within limits, the higher the frequency of sampling (i.e. shorter time increments) the more information can be gleaned from the data about pollutant sources, transport patterns, etc. As a minimum, one sample must be collected for each period equal to the averaging time of the standard. High frequency sampling may require significantly more data storage, either in computer or paper files.

More frequent sampling can give added information and can be averaged to calculate an average for comparison to the standard. Advantages of the information available from high frequency sampling include knowledge about transient events that may strongly influence on the longer average. Frontal passage through the area of the sampler are often marked by large changes in pollutant concentrations (Page 60: Figure 207.1) due to the changes in air mass history or

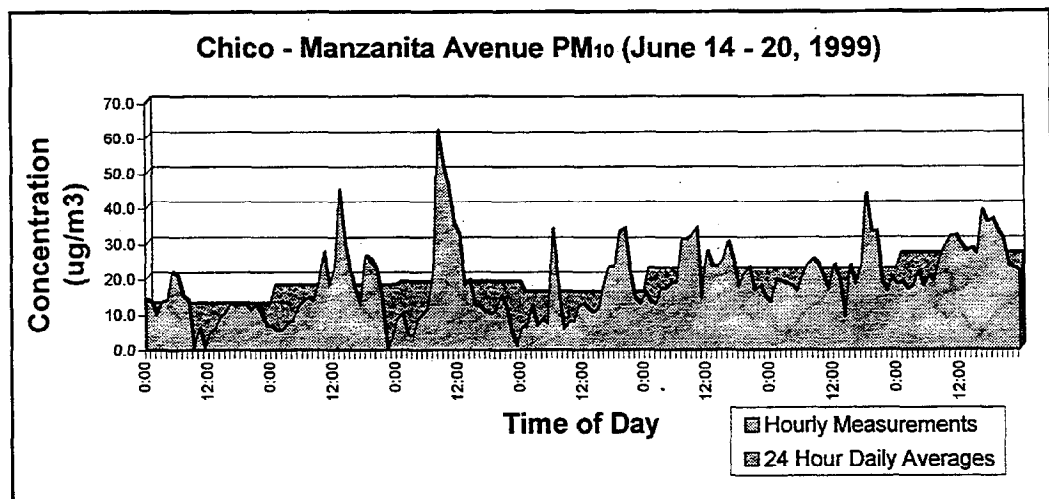


Figure 209.1 Comparison of Daily and Hourly PM₁₀ Averages

ventilation. They also are often marked by windy conditions that stir up large quantities of particulates. With resolution of an hour or less one can usually see the changes in upslope / downslope winds in mountainous areas. Figure 209.1 clearly illustrates the difference in information contained in hourly vs. daily average samples.

The new $PM_{2.5}$ monitoring includes 24-hour standards to provide protection against 24-hour peak concentrations and localized hot spots. The regulation also contains an annual standard (averaged over three years) to characterize wide-area particulate matter exposure levels associated with population health risks.

One of the principle determinants of sampling frequency is often the type of equipment being used. Manual methods (for example PM_{10}) typically are 24 hour samples for comparison with 24 hour and annual averages. Automated methods may give nearly instantaneous readings, many of which would be needed for even a one hour average. The performance specifications for automated methods (40 CFR 53 Subpart B) give a maximum lag time between a step change in input concentration and the first observable response of 20 minutes for SO_2 , Ozone, and NO_x monitors (10 minutes for CO monitors) and rise time to 95% of the final response of 15 minutes for SO_2 , ozone, and NO_x monitors (5 minutes for CO monitors).

209.3 ARTIFACTS AND INTERFERENCES

There are three major issues concerning artifacts and interferences: 1) pollutant removal to the structure of the sampling system; 2) volatilization of the pollutant; 3) absorption and conversion of gases by the filter or collected particulate.

209.3.1 Pollutant Removal

Most sampling systems are made of aluminum, plastic, or galvanized steel. These materials can absorb some gases (especially nitric acid). Besides removing the reactive gas from the air stream, this change can change the equilibrium between the gas phase and the solid, volatile particulate phase.

Nitric acid vapor is especially sensitive to removal in the sampling system. It has been found that aluminum surfaces, common in inlets and samplers, has an almost infinite capacity for absorbing nitric acid vapor while passing particles efficiently. Coating the surfaces with Teflon can largely eliminate this effect.

Denuders are often used to take advantage of this gas removal property. The reactive surface in a denuder (either the reactive material of the denuder itself, or a coating of reactive material) takes advantage of the fact that gas molecules diffuse through air much more rapidly than particles. The gas molecules migrate to the denuder surfaces and are removed while particles pass on through the denuder. This method is often used to determine the partitioning between nitric acid, sulfur dioxide, and ammonia gases and suspended particulate matter or prevent the positive bias caused by the adsorption of these gases by collected particulate matter on the filter.

The geometry of the air path can also cause the removal of particulate matter. This is not too much of a problem with $PM_{2.5}$; however, with PM_{10} and larger, significant quantities of particulate can be inertially removed by bends in the air path.

Some surfaces, particularly plastic, but also teflon-membrane and polycarbonate-membrane filters, can acquire an electric charge that may attract suspended particles. During weighing of filters on a microbalance the charge can produce biases in the filter weight. To dissipate the charge radioactive antistatic strips can be used. The most commonly used strips contain low levels of polonium-210 (Po^{210}). Antistatic coatings can also be used to increase the surface conductivity to facilitate the draining of electrostatic charges from nonmetallic materials to metallic materials.

209.3.2 Volatilization

Volatile compounds can also leave the filter after sampling and prior to weighing or chemical analysis. Nitrate is the most important volatile species usually found on filters. Losses of nitrate, ammonium, and chloride have been observed in excess of 50% from filters stored in unsealed containers at ambient temperatures for two to four weeks.

Temperature is by far the most important variable in loss of nitrate, although relative humidity and concentrations of ammonia and nitric acid vapor are also important in establishing the equilibrium between the gaseous and particulate phases. At temperatures above $30^{\circ}C$ most nitrate is in the nitric acid vapor phase, while at temperatures below $15^{\circ}C$ most is in the particulate phase, usually as ammonium nitrate.

Organic carbon analysis is also subject to volatilization biases. Particles may be composed of semi-volatile organic compounds and other organic gases may be adsorbed on particulate matter. Both of these forms of organic matter collected on the filter may be volatilized.

A third component of collected particulate matter that can be lost from the filter before analysis is water. Water vapor can adsorb or desorb from the filter at any time during or after sampling. Therefore, to assure uniformity, the filters must be equilibrated to a constant humidity. Particles collected at low relative humidity will gain water and those collected at high humidity will lose water until all are equilibrated to the same water content, negating the mass effect of differing ambient relative humidities.

Ambient relative humidity can also have an effect on the size of the particles. When ambient relative humidity exceeds 70% particle growth becomes significant. In studies of time and size differentiated particulate matter, this author has observed particle size changing in tandem with increasing and decreasing relative humidity.

209.3.3 Pollutant Gas Adsorption

Sulfur dioxide, oxides of nitrogen, nitric acid, and other acidic gases can be adsorbed by alkaline particles collected on a filter and the alkalinity of the filter itself resulting in a positive bias. The bias has been documented to be as high as $10 \mu\text{g}/\text{m}^3$. Filter acceptance testing can minimize the bias due to filter alkalinity.

This same principle has been used to collect acid gases on coated filters. Sulfur dioxide can be measured by absorption on potassium carbonate coated filters, ammonia on citric acid coated filters, and nitrogen dioxide on triethanolamine coated filters. Nitric acid can also be measured by collection on nylon filters and organic vapors by quartz-fiber filters.

210 REFERENCES

1. Miller, A., J. C. Thompson, R. E. Peterson, and D. R. Harrigan, 1983, *Elements of Meteorology*, 4th Edition, Charles E Merrill Publishing Co.
2. *Handbook of Chemistry and Physics*, 58th Edition, 1977, CRC Press.

3. Wallace, J. M. and P. V. Hobbs, 1977, *Atmospheric Science*, Academic Press.
4. Gieck, Kurt, 1983, *Engineering Formulas*, Fourth Edition, McGraw-Hill Book Company.
5. Commonwealth of Pennsylvania, *Fact Sheet: Air Pollution in Pennsylvania*, <http://www.dep.state.pa.us/dep/deputate/airwaste/aq/factsheets/fs1421.htm>.
6. Andreae, M.O. and P.J. Crutzen, 1997, Atmospheric Aerosols: Biogeochemical Sources and Role in Atmospheric Chemistry, *Science*, **276**:1052.
7. Finlayson-Pitts, B. J. and Pitts, Jr., J. N., 1997, Tropospheric Air Pollution: Ozone, Airborne Toxics, Polycyclic Aromatic Hydrocarbons, and Particles, *Science*, **276**:1045.
8. Hinds, W. C., 1982, *Aerosol Technology*, John Wiley & Sons.
9. U.S. EPA, 1997, *Fact Sheet: Health and Environmental Effects of Particulate Matter*.
10. U.S. EPA, 1996, *National Air Quality: Status and Trends*.
11. Mutters, R. and S. Soret, 1995, *Crop Losses from Air Pollutants; A GIS Regional Analysis and Statewide Crop Losses from Air Pollutants, Final Report*, ARB #A133-185 & 92-350.
12. Graedel, T. E., 1980, Atmospheric Photochemistry, In: *Reactions and Processes*, Springer Verlag.
13. Brimblecombe, P., 1996, *Air Composition and Chemistry*, Cambridge University Press.
14. Smith, W. H., 1981, *Air Pollution and Forests*, Springer-Verlag.
15. U.S. EPA, 1990, *Air Quality Criteria for Carbon Monoxide*, EPA 600/890/045F.
16. Wolf, P. C., 1972, Carbon Monoxide, in: *Our Chemical Environment*, Giddings, J. C. and M. B. Monroe, editors, Canfield Press.

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Graedel etc.

17. Ozone and the Atmosphere, Understanding Ozone, 1996, Atmospheric Chemistry and Data Resources, Goddard DAAC, http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/ATM_CHEM/understanding_ozone.html.
18. A Primer on Atmospheric Chemistry and Pollutant Transport, 1993, *The Air Pollution Consultant*.
19. New Jersey Department of Health and Senior Services, 1996, *Hazardous Substance Fact Sheet: Ozone*.
20. Heck, W.W., C. S. Furiness, E. B. Cowling, and C. K. Sims, 1998, Effects of Ozone on Crop, Forest, and Natural Ecosystems: Assessment of Research Needs, *EM*: October.
21. Heath, R. L., 1997, Oxidant Induced Alteration of Carbohydrate Production and Allocation in Plants, <http://www.rfl.psw.fs.fed.us/pubs/psw-gtr-164/fulltext/heath/heath.html>, Pacific Southwest Research Station.
22. Mudd, J. B., 1997, Biochemical Reactions of Ozone in Plants, <http://www.rfl.fs.fed.us/pubs/psw-gtr-164/fulltext/mudd/mudd.html>, Pacific Southwest Research Station.
23. Bowers, K. J., 1990, *The Calorimetric Determination of the Impact of Air Pollution on Pine Trees*.
24. U.S. EPA, 1996, *Criteria Pollutants*, <http://www.epa.gov/oar/oaqps/greenbk>.
25. U.S. EPA, 1998, *Nitrogen Dioxide*, <http://www.epa.gov/ngispgm3/iris/irisdat/0080.html>.
26. AEA Technology, 1996, *Chemistry of Atmospheric Pollutants*.
27. Manahan, S. E., 1972, *Environmental Chemistry*, Willard Grant Press.
28. Ayres, J. G., 1998, Health Effects of Air Pollution, <http://ci.mond.org/9621/962118.html>.
29. Keeley, J. E. and C. J. Fotheringham, 1997, Trace Gas Emissions and Smoke-Induced Seed Germination, *Science*, **276**:1248.

30. Natural Resources Canada: Minerals and Metals Sector, 1999, Canadian Lead Producers, <http://www.nrcan.gc.ca/ms/efab/mmsd/minerals/lead.htm>.
31. Shotyk, W., D. Weiss, P. G. Appleby, A. K. Cheurkin, R. Frei, M. Gloor, J. D. Kramers, S. Reese, and W. O. Van Der Knaap, 1988, History of Atmospheric Lead Deposition Since 12,370 ¹⁴C yr BP From a Peat Bog, Jura Mountains, Switzerland, *Science*, **281**:1635.
32. Nriagu, J. O., 1998, Enhanced Tales Told in Lead, *Science*, **281**:1622.
33. Craig, P. P., 1972, Lead, The Inexcusable Pollutant, in: *Our Chemical Environment*, Giddings, J. C. and M. B. Monroe, editors, Canfield Press.
34. California Air Resources Board, 1999, *California Air Pollution Control Laws*.
35. U.S. EPA, 1993, *Hydrogen Sulfide Report to Congress*, EPA 453/R-93-045.
36. U.S. EPA, 1998, *IRIS Substance File - Hydrogen Sulfide*, <http://www.epa.gov/ngispgm3/iris/subst/0061.htm>.
37. Laengrich, A. R., and W. L. Cameron 1978, Tail Gas Cleanup Addition May Solve Sulfur-Plant Compliance Problem, *The Oil and Gas Journal*.
38. California Air Resources Board, Toxic Air Contaminant List, <http://arbis.arb.ca.gov/toxics/tac/taclist.htm>.
39. Aneja, V. P., G. C. Murray, and J. Southerland, 1998, Atmospheric Nitrogen Compounds: Emissions, Transport, Transformation, Deposition, and Assessment, *EM*:April.
40. Raloff, J., 1995, When Nitrate Reigns: Air Pollution Can Damage Forests More Than Trees Reveal, *Science News*, **147**:90.
41. Berg, B. and E. Matzner, 1997, Effect of N Deposition on Decomposition of Plant Litter and Soil Organic Matter in Forest Systems, *Environmental Review*, **5**:1.
42. Lin, X., P. B. Roussel, O. T. Melo, and P. M. Selorio, 1995, The Role of

- Toronto Urban Emissions in Regional Ozone Episodes, *Atmospheric Environment*, **29**:565.
43. U.S. EPA, 1997, Nitrogen Oxides: Impacts on Public Health and the Environment.
44. Chow, J. C. and J. G. Watson, 1998, *Guideline on Speciated Particulate Sampling*, Desert Research Institute.
45. Husar, H. B., J. P. Lodge, Jr., and D. J. Moore, editors, 1978, *Sulfur in the Atmosphere, Proceedings of the International Symposium*, Pergamon Press.
46. U.S. EPA, 1999, *Visibility and Air Pollution*, <http://www.epa.gov/airprogmoar/vis/overview.html>.
47. Chestnut, L. G., 1995, Human Health Benefits from Sulfate Reductions under Title IV of the 1990 Clean Air Act Amendments.
48. Gard, E. E., M. J. Kleeman, D. S. Gross, L. S. Hughes, J. O. Allen, B. D. Morrical, D. P. Fergenson, T. Dienes, M. E. Galli, R. J. Johnson, G. R. Cass, and K. A. Prather, 1998, Direct Observation of Heterogeneous Chemistry in the Atmosphere, *Science*, **279**:1184.
49. IMPROVE, 1994, Visibility Protection.
50. Miller, D. F., A. J. Alkezweeny, J. M. Hales, and R. N. Lee, 1978, Ozone formation Related to Power Plant Emissions, *Science*, **202**:1186.
51. Meng, Z., D. Dabdub, and J. H. Seinfeld, 1997, Chemical Coupling Between Atmospheric Ozone and Particulate Matter, *Science*, **277**:116.
52. Cahill, T. A., 1989, Monitoring of Atmospheric Particles and Ozone in Sequoia National Park: 1985-1987, California Air Resources Board Final Report, AS-180-32.
53. Ewell, D. M., R. G. Flocchini, L. O. Myrup, and T. A. Cahill, 1989, Aerosol Transport in the Southern Sierra Nevada, *J. Appl. Met.*, **28**:112.

54. Cahill, T. A., J. J. Carroll, D. Campbell, and T. E. Gill, 1996, *Air Quality in the Sierra Nevada Ecosystem Project: Final Report to Congress*, Chapter 48, Vol II.
55. Bohm, M., B. McCune, and T. Vandetta, 1991, Diurnal Curves of Tropospheric Ozone in the Western United States, *Atmospheric Environment*, **25A**:1557.
56. Cahill, T. A., R. A. Eldred, L. L. Ashbaugh, and K. Bowers, 1997, Fine Particulate Matter in the Cascade, Sierra Nevada, and San Bernardino Mountains, Proceedings, Air and Waste Management Association Conference on Visibility and Air Quality - Aerosols and Global Radiation Balance.
57. Sturgess, J. M., 1985, Mucociliary Clearance and Mucus Secretion in the Lung, in: *Toxicology of Inhaled Materials*, H. P. Witschi and J. D. Brain eds., Springer-Verlag.
58. Stankunas, A. R., D. F. Unites, and E. F. McCarthy, 1983, *Air Pollution Damage to Man-Made Materials: Physical and Economic Estimates*, Electric Power Research Institute.
59. Yocom, J. E. and N. Grappone, 1976, *Effects of Power Plant Emissions on Materials*, Electric Power Research Institute.
60. Howitt, R., 1993, *Economic Assessment of Acid Deposition and Ozone Damage on the San Joaquin Valley Agriculture*, California Air Resources Board.
61. Hogsett, W. E., J. E. Weber, D. Tingey, A. Herstrom, E. H. Lee, and J. A. Laurence, 1997, Environmental Auditing: An Approach for Characterizing Tropospheric Ozone Risk to Forests, *Environmental Management*, **21**:105.
62. Power, W. and L. S. McCarthy, 1997, Fallacies in Ecological Risk Assessment Practices, *Environmental Science and Technology*, **31**:370A.

This chapter of the manual consists of the legal requirements for ambient air monitoring. As such, the chapter will discuss state and federal air quality standards, attainment designations, and the monitoring program requirements.

301 AMBIENT AIR QUALITY STANDARDS

The goal of air pollution control programs is to reduce air pollutant concentrations in areas with excess levels and to prevent the increase of pollutants in clean air areas. Ambient air quality standards have been set as the line of demarcation between pollutant concentrations considered clean and concentrations considered needing improvement. The criteria for the standards have been established, after research, to protect human health (primary standards) and welfare (secondary standards).

Comparison of the ambient air quality data with the standards forms the basis of a number of decisions (Figure 301.1).

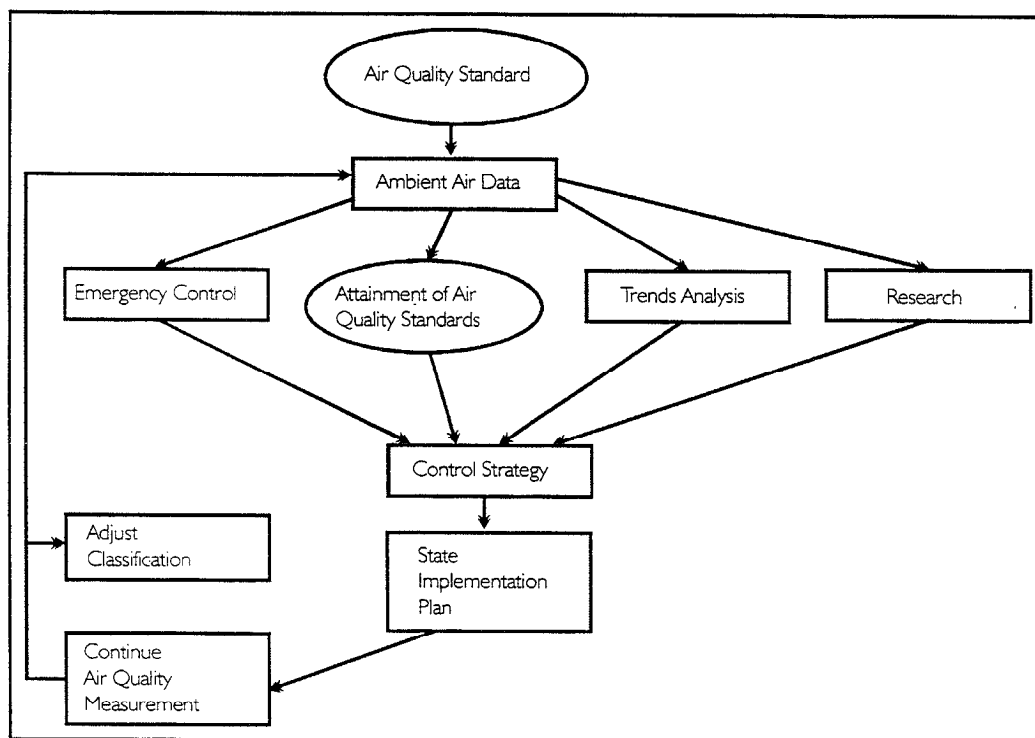


Figure 301.1 Decision Related to Ambient Air Quality Standards and Monitoring Data

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301.1 NATIONAL AMBIENT AIR QUALITY STANDARDS (NAAQS)

The National Ambient Air Quality Standards (NAAQS)¹ are maximum acceptable concentrations of criteria pollutants in the atmosphere. They form uniform air quality targets applicable across the country and so provide a consistent set of rules and goals.

The NAAQS program is the foundation of most other Clean Air Act Title I programs.² Specifically: 1) attainment / nonattainment area designations; 2) the control strategies needed for a given area to achieve and maintain the NAAQS are spelled out in state implementation plans (SIPs) required to be submitted by all states; and 3) the construction and modification of major sources of criteria pollutants is governed by the prevention of significant deterioration (PSD), new source review (NSR), and new source performance standards (NSPS) programs.

When the Clean Air Act was amended in 1970, Congress directed the EPA to develop numerical standards for the major pollutants of concern (criteria pollutants) in the ambient air. Thus was born the NAAQS program. The six original pollutants addressed were: sulfur dioxide, total suspended particulate matter, carbon monoxide, photochemical oxidants, hydrocarbons, and nitrogen oxides.

Over the years lead has been added to the NAAQS and hydrocarbons removed; photochemical oxidants was changed to ozone; and total suspended particulate matter has been changed to PM_{10} . Recently $PM_{2.5}$ fine particulate matter was added. Table 301.1 reflects the current NAAQS and their associated concentration limits, averaging times, and the form of each standard.

Recognizing that new toxicological, technological, and ecological data would become available, Congress has specified that the EPA must review each NAAQS every five years. If that review indicates that the NAAQS merits modification, appropriate regulatory action is required.

301.2 CALIFORNIA AMBIENT AIR QUALITY STANDARDS

The state of California has promulgated ambient air quality standards similar to the NAAQS (Table 301.1). The California standards are at least as stringent as the federal standards, but are designed to address specific issues of interest in California. For example: the California standards include a stricter standard for CO in the Lake Tahoe basin. This is needed since the air is thinner at high elevations, providing less oxygen available for breathing, thus the ambient CO

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Ambient Air Monitoring

Table 301.1 Ambient Air Quality Standards

| Pollutant | Averaging Time | California Concentration Standard | Form of the Standard | Federal Concentration Standard | | Form of the Standard |
|---|-----------------------------|---|------------------------|------------------------------------|-----------------------------------|---|
| | | | | Primary | Secondary | |
| Ozone (O ₃) | 1 Hour | 0.09 ppm (180 µg/m ³) | Not to exceed | 0.12 ppm (235 µg/m ³) | Same as Primary | No more than one day per calendar year with an expected maximum concentration greater than the standard |
| | 8 Hour | --- | --- | 0.08 ppm (157 µg/m ³) | | Fourth highest eight hour concentration in a year, averaged over three years |
| Respirable Particulate Matter (PM ₁₀) | Annual Geometric Mean | 30 µg/m ³ | Not to exceed | --- | Same as Primary | --- |
| | 24 Hour | 50 µg/m ³ | Not to exceed | 150 µg/m ³ | | 99% of the daily concentrations, averaged over three years, are equal to or less than the standard |
| | Annual Arithmetic Mean | --- | --- | 50 µg/m ³ | | Less than or equal to |
| Fine Particulate Matter (PM _{2.5}) | 24 Hour | No Separate State Standard | --- | 65 µg/m ³ | Same as Primary | 98% of the daily concentrations, averaged over three years, are equal to or less than the standard |
| | Annual Arithmetic Mean | | | 15 µg/m ³ | | Less than or equal to |
| Carbon Monoxide (CO) | 8 Hour | 9.0 ppm (10 mg/m ³) | Not to exceed | 9 ppm (10 mg/m ³) | None | Not to exceed more than once per calendar year |
| | 1 Hour | 20 ppm (23 mg/m ³) | Not to exceed | 35 ppm (40 mg/m ³) | | |
| | 8 Hour (Lake Tahoe) | 6 ppm (7 mg/m ³) | Not to equal or exceed | --- | | |
| Nitrogen Dioxide (NO ₂) | Annual Arithmetic Mean | --- | --- | 0.053 ppm (100 µg/m ³) | Same as Primary | Not to exceed |
| | 1 Hour | 0.25 ppm (470 µg/m ³) | Not to exceed | --- | | --- |
| Lead | 30 Day | 1.5 µg/m ³ | Not to equal or exceed | --- | --- | --- |
| | Calendar Quarter | --- | --- | 1.5 µg/m ³ | Same as Primary | Not to exceed |
| Sulfur Dioxide (SO ₂) | Annual Arithmetic Mean | --- | --- | 0.030 ppm (80 µg/m ³) | --- | Not to exceed |
| | 24 Hour | 0.04 ppm (105 µg/m ³) | Not to exceed | 0.14 ppm (365 µg/m ³) | --- | Not to exceed more than once per calendar year |
| | 3 Hour | --- | --- | --- | 0.5 ppm (1300 µg/m ³) | Not to exceed more than once per calendar year |
| | 1 Hour | 0.25 ppm (655 µg/m ³) | Not to exceed | --- | --- | --- |
| Visibility Reducing Particles | 8 Hour (10 am to 6 pm, PST) | b _{ext} > 0.23, visibility < 10 miles (0.07 and 30 miles for Lake Tahoe) due to particles; with RH < 70% | Not to exceed | No Federal Standards | | |
| Sulfates | 24 Hour | 25 µg/m ³ | Not to equal or exceed | | | |
| Hydrogen Sulfide | 1 Hour | 0.03 ppm (42 µg/m ³) | Not to equal or exceed | | | |

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has the potential for greater health effects. Therefore, a lower standard is needed to assure the health protection required of the air standards, although it was not provided in the NAAQS.

301.3 AMBIENT AIR QUALITY STANDARDS CRITERIA

Ambient air quality standards have been established as measurement guidelines for evaluating pollutant levels. The guidelines consist of the type of standard, concentration (level of the standard), form of the standard, and averaging time. The scientific basis for the standards must acknowledge that continuing research is needed to address unanswered questions and refine the state of knowledge of the impact of pollutants on health and welfare. In response to that evolving level of knowledge, the standards and monitoring methods must be periodically reviewed and updated.

301.3.1 Primary Standards

The primary ambient air quality standards are designed to be protective of public health. As a guiding principle, the primary standards have been set in accordance with health effects scientific research and include a margin of safety and a consideration for economic impact of the regulations needed to control the air pollutant emissions.

The most common health effects of ambient air pollutants are respiratory: reduced lung function, asthma, lung damage, and bronchitis. Additional health effects may include: eye irritation, reduced resistance to colds and infections, increased incidence of heart disease, brain and nervous system damage, carcinogenicity, mutagenicity, and teratogenicity. Section 202 of Chapter 200 describes the health effects of individual pollutants.

301.3.2 Secondary Standards

Secondary ambient air quality standards define levels of air quality deemed necessary to protect the public welfare from adverse effects of a pollutant. Adverse effects may range widely from property damage (damage to rubber and fabric, erosion of building materials, statuary, and monuments, soiling and discoloration, and electrical short circuits) to environmental effects (physical and physiological damage to plants and animals; reduced visibility; and acidification of lakes, streams, and rivers). As with primary standards, the public welfare effects of individual pollutants is described in Section 202 and Chapter 200.

301.3.3 Level of the Standard

The level of the standard refers to the concentration at which the effects of the pollutant have been deemed to have become significant, with a margin of safety to assure protection of sensitive individuals. When people think of the ambient air quality standards, they typically think of the level of the standard. However, the form and averaging time are also of critical importance in determining attainment and in evaluating the expected effects for a level of pollutant concentration.

301.3.4 Averaging Time

Averaging time is generally related to whether acute or long term effects are of most concern. The time intervals of the ambient air standards are from one hour to annual averages (Table 301.1); although the one hour average ozone standard is being phased out in favor of the newer eight hour ozone standard.

In those areas that meet the one hour ozone standard the one hour standard has been revoked and only the eight hour standard applies. The one hour standard still applies to those areas that do not yet meet it. When those areas meet the one hour standard it will be revoked there also and replaced by the eight hour standard.

The relationship between ozone concentrations and averaging time has been extensively studied. Being a secondary pollutant, ozone concentrations exhibit a pronounced diurnal curve. The amplitude and timing of the peak and minimum levels is related to the proximity to the source area. Receptors and monitoring stations near the source area show strong peaks and valleys of concentrations while distant sites show much lower variability.³ In this manner urban ozone concentrations may have a high one hour ozone concentration and a seemingly low eight hour concentration. In rural areas the reverse may be true, a relatively low one hour concentration and a higher eight hour concentration than may otherwise be expected. This leads to the surprising result that the daylight average ozone in Sequoia National Park is quite comparable to that in Los Angeles (0.083 ppm and 0.072 ppm at Ash Mountain and Giant Forest vs. 0.085 ppm at San Bernardino). By comparison, the one hour peak concentrations at Ash Mountain and Giant Forest were 0.087 ppm and 0.103 ppm vs. San Bernardino at 0.140 ppm.⁴ (27 July - 24 September, 1987)

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301.3.5 Form of the Standard

The form of the standard relates to how attainment / nonattainment is determined and affects the amount of air quality improvement needed. The simplest form of the standard is for the standard to be a level not to be exceeded or not to be equaled or exceeded. California ambient air quality standards are written in these terms.

The federal standards are, in cases, much more complex (i.e. "Form of the Standard" column, Table 301.1. Using a percentile form, as with the 24 hour federal particulate matter standards allows the highest values to be ignored when determining attainment of the standards.

The federal ozone standard states that the expected number of exceedances per year must be less than or equal to one. The statistical term "expected number" is basically an arithmetic average. At the end of each year the number of days with maximum hourly concentrations above 0.12 ppm is determined. This number is averaged with the number of days with maximum hourly concentrations above 0.12 for the previous two years. As long as this number is less than or equal to one, the area is in attainment.

301.3.6 Reference Conditions

Reference conditions for both California and Federal ambient air quality standards are: 25°C and 760 mmHg; ppm refers to part per million by volume. Measurements must be corrected to this temperature and pressure before comparison to the standard. However, particulate samplers, where a particulate diameter cut point must be maintained, must operate at the proper flow rate measured in actual conditions at the site and the results later calculated in terms of the reference conditions.

For most calculations, rounding is accomplished by rounding halves up (i.e. if the standard is 0.1, values of 0.05 or more are rounded up, values less than 0.05 are rounded down).

301.3.7 Spatial Averaging

The new NAAQS for PM_{2.5}, currently being implemented, allows the spatial averaging of data from multiple monitoring points for the annual average standard. Many of the epidemiological studies examined in developing the standard

used spatial averages to characterize area-wide exposure levels and the associated population health risk. Thus, an annual average standard based on spatially averaged concentrations would better reflect the wide-area particulate matter exposure levels. The 24-hour standard is intended to work in conjunction with the spatially averaged annual standard by providing protection against 24-hour peak concentrations, i.e. local hot spots. The concept of spatial averaging is supported by studies that have shown a general uniformity of fine particulate matter concentrations across reasonably wide mixing areas.

For spatial averaging to result in appropriate averages, particular care must go into establishing the network of samplers over which the average will be calculated. The 40 CFR 58 siting rules delineate that the samplers to be averaged must be population-oriented samplers influenced by similar sources and must meet homogeneity constraints.

Spatial averaging also provides added flexibility to the standard and is appropriate for visibility monitoring.

301.4 SPECIAL EVENTS AND SPECIAL CONDITIONS

On occasion, special events and conditions can cause an exceedance of the NAAQS. Most commonly these events cause exceedance of the particulate matter standard; although all criteria pollutants can be exceeded. When a special event or condition occurs the data submitted to the EPA AIRS data base is marked with a flag noting that additional information is available or that special treatment and consideration for waiver from the NAAQS is requested.⁶

There are a number of situations in which a data flag may be applied to request regulatory relief. They may be categorized as either special events or special conditions, depending on the circumstances and supporting information.

- **Special Events** - Discrete occurrences, either anthropogenic or nonanthropogenic, that are not likely to recur.
- **Special Conditions** - Well documented circumstances that can have a significant influence on the ambient pollutant concentrations and are of a recurring nature. They may result, for instance, from anthropogenic emissions originating outside the United States or nonanthropogenic emissions, such as wind blown dust from nonanthropogenic sources.

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Three types of flags may be used on the data:

- **Information "I" Flag** - Used to notify the data user that additional information is available about a special condition that occurred during the sample. The "I" flag is not used to indicate that the data are affected by a potential special event.
- **Validity "V" Flag** - Indicates that the data have been reviewed and validated by the reporting agency.
- **Treatment "T" Flag** - Used to notify the EPA that the reporting agency intends to seek relief from regulatory requirements because of the affect of a potential special event.

In general, the EPA expects to exclude data influenced by special events from comparison with the NAAQS. In this way only data which are representative of the area's expected air quality are used to dictate control requirements and strategies for that area.

Data that result from special conditions (i.e. data from events that are likely to recur) are not eligible for exclusion from NAAQS comparisons. However, in some cases, such data may be used to support a request for a waiver of serious nonattainment control requirements or attainment dates.

301.4.1 Qualifying Tests

In order to receive regulatory relief, supplemental information must be submitted to the EPA. This additional information must address the recurrence and causation of the event. If both the recurrence and culpability test are satisfied, then the claim for special treatment may be granted.

- **Recurrence Test** - The event's likelihood of recurrence.
- **Culpability Test** - The causal relationship between the event and the measured air quality data.

Likelihood of recurrence is not absolutely defined, it is based on historical information. If the event is a random event occurring no more than once in five years it may be considered not likely to recur.

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The culpability test is used to establish the causal relationship between a qualifying event and the data values. It must be based on raw data such as air quality data, meteorological data, and traffic counts; monitor operation; and modeling and/or filter analysis.

301.4.2 Qualifying Events

The following list provides an explanation of several categories of events and conditions that may be used to describe circumstances affecting data values that may merit special treatment or handling of monitoring data.⁶ It is important to note that this list is not exhaustive; it is intended to provide descriptive information about conditions encountered by various state and local reporting agencies in past data flagging experiences.

High Winds - PM - High winds combined with high particulate matter levels due to suspension or resuspension of particulate matter. The event description should contain information demonstrating the presence of an hourly wind speed of greater than the normal peak prevailing wind conditions for the area and no (or only trace) precipitation.

Stratospheric Ozone Intrusion - O₃ - A stratospheric ozone intrusion occurs when a parcel of air originating in the stratosphere (average height 20 km) is entrained directly to the surface of the earth.

Volcanic Eruptions - CO, SO₂, NO₂, PM - The emission or ejection of volcanic materials at the earth's surface from a crater or fissure.

Sandblasting - PM - Sandblasting refers to the temporary use of abrasive blasting with pressurized air for surface preparation purposes at a given location.

Vegetative Fires - CO, PM - Any fire in which vegetative matter is burned. The freeform comment field in AIRS reports should include an indication of what type of vegetative matter was burned (e.g. forest, rangeland, etc.) and the type of fire. Fire types may include:

- **Wildfire** - generally defined as an uncontrolled fire in vegetation started by nature, arson, or accident that requires suppressive action to protect natural resources or values associated with natural resources, as well as private property.

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- Prescribed natural fire - a wildfire for which a conscience decision has been made by a land manager to allow the fire to burn in a controlled and restricted manner for a land management purpose.
- Prescribed fire - a fire intentionally ignited by a land manager for land management purposes (e.g. ecosystem improvement, hazard reduction, etc.)

The fires should be classified by size using the designations in Table 301.2. Class A and B fires are generally associated with monitoring data collected on a microscale or middle scale range from the fire, while Class C and larger fires would also be expected to affect data collected within a neighborhood, urban, or regional scale.

Table 301.2 Class and Size Designations of Forest Fires

| Class | Size (acres) |
|-------|---------------|
| A | ≤ 0.25 |
| B | 0.26 - 9.9 |
| C | 10 - 99.9 |
| D | 100 - 299.9 |
| E | 300 - 999.9 |
| F | 1000 - 4999.9 |
| G | ≥ 5000 |

Structure Fires - CO, PM - Any fire involving some kind of structure, such as building, residence, industrial complex, or commercial establishment.

High Pollen Count - PM - A pollen above 25 grains/cm² or 1000 grains per cubic meter. The pollen count index is usually obtained one of two ways: 1) by use of a coated slide mounted on a circular plate that is generally mounted on the top of a seven or eight story building with unobstructed air flow, or 2) a volumetric method (counting the number of grains of pollen on a filter with a known air flow i.e. the number of grains per cubic meter). Other recognized methods for measuring pollen levels may be used.

Chemical Spills and Industrial Accidents - CO, SO₂, NO₂, PM - The emissions that result from accidents such as fires, explosions, power outages, train derailments, vehicular accidents, or a combination of these.

Traffic Patterns - CO - A condition resulting from a major accident (rather than frequent minor accidents) or short duration obstructions, such as demolition or construction. During these conditions the level of traffic may increase until it exceeds the maximum capacity the street or highway. Speeds are generally reduced and stoppages may occur because of the downstream congestion.

Construction/Demolition - PM - The building, destroying, or renovation of any

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residential, institutional, commercial, or industrial building, structure, facility, or installation.

Agricultural Tilling - PM - The act of preparing dry soil for cultivation or for controlling the growth of weeds by the use of mechanical devices during periods with an hourly wind speed greater than expected for that area.

Highway Construction - PM - The act of building a new, or repairing an existing, highway, road, or street.

Rerouting of Traffic - CO - A temporary deviation or detour of vehicular traffic because of an accident, construction, or demolition.

Salting/Sanding of Streets - PM - The application of salt and/or sand to the road to increase traction and/or prevent the surface water from refreezing after it has melted.

Infrequent Large Gatherings - CO, PM - A gathering of more than 10,000 people (5,000 cars) at any one time and at a single location. Unusual traffic congestion may be associated with the event.

Roofing Operations - PM, SO₂ - The process of building, repairing, or recoating the external upper covering of a house or building that involves the application of a petroleum-based material (usually heavy residuals from a refining operation) of a roof. The materials heated and then sprayed or rolled onto the surface.

Cleanup After a Major Disaster - CO, PM, SO₂ - For purposes of flagging, major disasters are serious public misfortunes for which State or Federal relief has been granted.

Industrial Plant Start-Ups, Shut-Downs, Process Upsets, or Control Equipment Malfunctions - O₃, NO₂, PM, CO, SO₂, Pb - Emissions that result from plant start-ups, shutdowns, process upsets, or control equipment malfunction or a combination of these. These activities are temporary conditions with special reporting requirements. If the emissions constitute noncompliance it is not considered a special event.

International Pollutant Transport - PM - Transport of particulate matter over international borders. The original source of this pollution may be anthropo-

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genic or nonanthropogenic. This category may also be used to document recurring special conditions with an information ("I") flag.

Other Types of Events - O_3 , CO, PM, SO_2 , NO_2 , Pb - This category indicates events that are not adequately described by one of the other descriptors. (As appropriate, EPA will add descriptor codes.)

Other Types of Conditions - O_3 , CO, PM, SO_2 , NO_2 , Pb - This reporting code may be used for two purposes. The first is to document a special condition that is not adequately described by the other descriptor codes. The second use is to provide general information on a data value that may be of interest to users of the data. This second case does not imply that the data will be treated as a special condition, it only serves to inform others of the circumstances surrounding a data value.

301.5 ATTAINMENT/NONATTAINMENT

Attainment or nonattainment designation describes whether or not (respectively) an area meets the air quality standards. Some areas are designated as "unclassifiable". Unclassifiable areas do not have sufficient information to be designated as either attainment or nonattainment, typically because of a lack of monitoring data. Because a separate determination is made for each pollutant, each area may be attainment for some pollutants, but not for others.

302 ATTAINMENT AND NONATTAINMENT AREAS

Air basins and portions of air basins that do not meet the ambient air quality standards are termed "nonattainment". Those areas that meet the standards are termed "attainment" and those that the attainment status hasn't been established, usually because the pollutant has not been sampled for, are termed "unclassifiable." Nonattainment areas for ozone, particulate matter, and CO are further classified depending on the severity of the violation of the NAAQS. Certain areas where pristine conditions are especially valuable (e.g. national parks) are designated as Class I areas and are accorded special protection from visible pollutants such as particulate matter, SO_2 , and NO_x .

Each state is required to have a control strategies plan, the State Implementation Plan (SIP), listing the means that will be employed to attain and maintain compliance with the NAAQS. Control in nonattainment areas become progressively more stringent as the degree of violation becomes more severe (Table 302.1). In

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Table 302.1 Requirements for NAAQS Nonattainment Areas²

| Pollutant | Area Classification | Primary Standard Attainment Date | Major Source Threshold | Required Offset Ratio |
|------------------|--|----------------------------------|---|-----------------------|
| Carbon Monoxide | Moderate | 31 Dec 1995 | 100 tpy CO | NA |
| | Serious | 31 Dec 2000 | 50 tpy CO | NA |
| Lead | NA | 15 Nov 1995 ^a | 100 tpy lead | NA |
| NO ₂ | NA | 15 Nov 1995 ^a | 100 tpy NO ₂ | NA |
| Ozone | Marginal | 15 Nov 1993 | 100 tpy VOC or NO _x ^b | 1.1:1 |
| | Moderate | 15 Nov 1996 | 100 tpy VOC or NO _x ^b | 1.15:1 |
| | Serious | 15 Nov 1999 | 50 tpy VOC or NO _x ^b | 1.2:1 |
| | Severe - 15 | 15 Nov 2005 | 25 tpy VOC or NO _x ^b | 1.3:1 ^c |
| | Severe - 17 | 15 Nov 2007 | 25 tpy VOC or NO _x ^b | 1.3:1 ^c |
| | Extreme | 15 Nov 2010 | 10 tpy VOC or NO _x ^b | 1.5:1 ^c |
| | Transport Region not classified as serious, severe, or extreme | 15 Nov 1996 | 50 tpy VOC, 100 tpy NO _x | 1.15:1 |
| PM ₁₀ | Moderate | 31 Dec 1994 | 100 tpy PM ₁₀ ^d | NA |
| | Serious | 31 Dec 2001 | 70 tpy PM ₁₀ ^c | NA |
| SO _x | NA | 15 Nov 1995 | 100 tpy SO _x ^a | NA |

^aor five years after redesignation to nonattainment; ^bEPA may exempt certain major NO_x sources where NO_x reductions would not contribute to attainment of the NAAQS; the major source threshold applies to VOC or NO_x, but not to combined emissions; ^cthe required offset is 1.2:1 for states that require all existing major sources in the nonattainment area to use BACT for control of VOC emissions; ^dor six years after redesignation to nonattainment; ^eor ten years after redesignation to nonattainment

addition, the time allocated for that area to reach attainment is extended in the more severe violation areas; in recognition that more extensive controls will be needed in those areas.

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302.1 CLASSIFICATION OF OZONE NONATTAINMENT AREAS

The classification of ozone nonattainment areas is based on the concept of design value. While both the ozone and CO NAAQS call for nonattainment classification based on design value, the design values are calculated differently due to the differing forms of the standards.⁵

302.1.1 Ozone Design Values

Calculations of the ozone design value use three years of data. The data used are the daily maximum ozone values. A separate design value is calculated for each site in an area that does not meet the NAAQS and the highest of these design values is the design value for the area. For an area to meet the NAAQS all locations within that area must meet the NAAQS.

In its simplest form, the ozone standard requires that the average number of exceedances cannot be more than one per year, over a three year period. An area with four exceedances during a three year period, therefore, does not meet the NAAQS since four exceedances averaged over three years results in an average of more than one exceedance per year (i.e. an average of 1.3 exceedance per year). In this case, the fourth highest value would become the design value. This assumes three complete years of data with no missing data. If only two complete years of data are available, then the third highest value is used, and if only one year of data is available, the second highest is used. A year is considered complete if valid daily maximums are available for at least 75% of the ozone season. For an area, data are combined over multiple years, but not from different sites, the design value for the area is the highest site specific design value.

Table 302.3 Hypothetical Ozone Results for Design Value Calculation

| Site | Year | Maximum | 2nd high | 3rd high | 4th high |
|--------|------|---------|----------|----------|----------|
| Site 1 | 1996 | 0.127 | 0.123 | 0.122 | 0.110 |
| | 1997 | 0.129 | 0.124 | 0.121 | 0.116 |
| | 1998 | 0.142 | 0.136 | 0.134 | 0.115 |
| Site 2 | 1996 | 0.110 | 0.100 | 0.095 | 0.90 |
| | 1997 | 0.110 | 0.100 | 0.095 | 0.90 |
| | 1998 | 0.180 | 0.175 | 0.160 | 0.110 |

As a hypothetical example, the following two sites (Table 302.2) are used to calculate individual and area design values. At each site, each year is at least

75% complete. The design value for Site 1 is 0.129 (the fourth highest daily maximum value during these three years. For Site 2 the design value is 0.110. For the area, the design value would be 0.129, the higher of the design values in the area. Assuming no missing data, the second site would meet the NAAQS, but the area would not.

In calculating the design values, the high values for a year are considered, even if the data for that year did not satisfy the 75% data completeness criterion. For example, if a site had two years of data that met the 75% data completeness criterion and one year that did not, then the third highest value during the three year period would be the design value. Recall from above that with two complete years the third highest, rather than fourth highest, value should be used for the design value, but the data from all three years is used. This ensures that valid high measurements are not ignored simply because other data in that year were missing.

Data completeness for new sites that have just come on line is applied beginning the first day of actual monitoring, as long as the data set is at least 75% complete for June through August.

In the case in which no year in the three year period meets the 75% requirement, but at least 90 days of valid data exist for the period a design value can still be calculated. Divide the number of valid daily maxima during the three year period by the required number of monitoring days per year. Add 1.0 to the above result. The integer portion of the result is the rank that determines the design value. For example, a site with a required ozone monitoring season of 214 days reports 40, 121, and 130 valid days of ozone data. Step one would give $(40+121+130)/214 = 1.36$. Add 1.0 to this value to get 2.36. The integer portion of this is 2. Therefore the second highest value in the three year period is the design value.

302.1.2 Ozone Classifications

Once the design value has been calculated it can be used to determine the severity classification for an area of ozone nonattainment.

- Extreme - Design value 0.280 ppm and above
- Severe 17 - Design value of 0.190 ppm to 0.280 ppm

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- Severe 15 - Design value of 0.180 ppm to 0.190 ppm
- Serious - Design value of 0.160 ppm to 0.180 ppm
- Moderate - Design value of 0.138 ppm to 0.160 ppm
- Marginal - Design value of 0.121 ppm to 0.138 ppm
- Submarginal - Areas that violate the ozone standard and have a design value of less than 0.121 ppm
- Transitional - An area designated as an ozone nonattainment area as of the date of the enactment of the 1990 Clean Air Act Amendments, but has not violated the primary ambient air quality standard for ozone for the 36 month period between 1 January 1987 through 31 December 1989.
- Incomplete (or no) data - An area designated as an ozone nonattainment area as of the enactment of the 1990 Clean Air Act Amendments and did not have sufficient data to determine if it is meeting or not meeting the ozone standard.

302.2 CLASSIFICATION CARBON MONOXIDE NONATTAINMENT AREAS

There are computational differences between the procedures for ozone and carbon monoxide design values chiefly because of differences in the form of the standards. While the NAAQS for ozone is structured as expected exceedances over three years, the carbon monoxide standard is structured using the older "once per year" format. The CO design values are also based on two years of data rather than the three years for ozone. Another difference is that the ozone NAAQS uses the daily maximum value while the CO NAAQS uses running eight-hour averages so that, even though they must be non-overlapping, it is possible to have more than one CO exceedance per day.

302.2.1 Carbon Monoxide Design Values

Carbon monoxide design values are discussed in terms of the eight-hour NAAQS, rather than the one-hour standard because the eight-hour standards is typically the standard of concern. However, the one-hour design value would be calculated in the same manner. Select the highest and second highest values at a site for the past two years. The highest of the second highs is the design value

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for that site. The highest site-wise design value becomes the design value for an area. For each site individual years of CO data are considered separately to determine the highest and second highest values. If an area has a design value greater than 9 ppm (greater than or equal to 9.5 ppm to adjust for rounding), it mean that there was at least one monitoring site where the second highest (non-overlapping) eight-hour value was greater than 9 ppm in at least one year. Therefore, there were at least two values above the standard during one year at that a site and, thus, the standard was not met.

Table 302.4 Hypothetical CO Highest and Second Highest Values

| Site | Year | Highest Eight-Hour Value | Second Highest Eight-Hour Value |
|--------|------|--------------------------|---------------------------------|
| Site 1 | 1997 | 14.6 | 8.9 |
| | 1998 | 13.9 | 10.9 |
| Site 2 | 1997 | 12.2 | 11.1 |
| | 1998 | 10.8 | 10.4 |

In a hypothetical case for an area with two CO monitoring stations, given the data in Table

302.4, the design value for Site 1 is 10.9 and the design value for Site 2 is 11.1. The design value for the area containing these two monitoring stations is 11.1. Thus, this area exceeds the NAAQS for carbon monoxide.

302.2.2 Carbon Monoxide Classifications

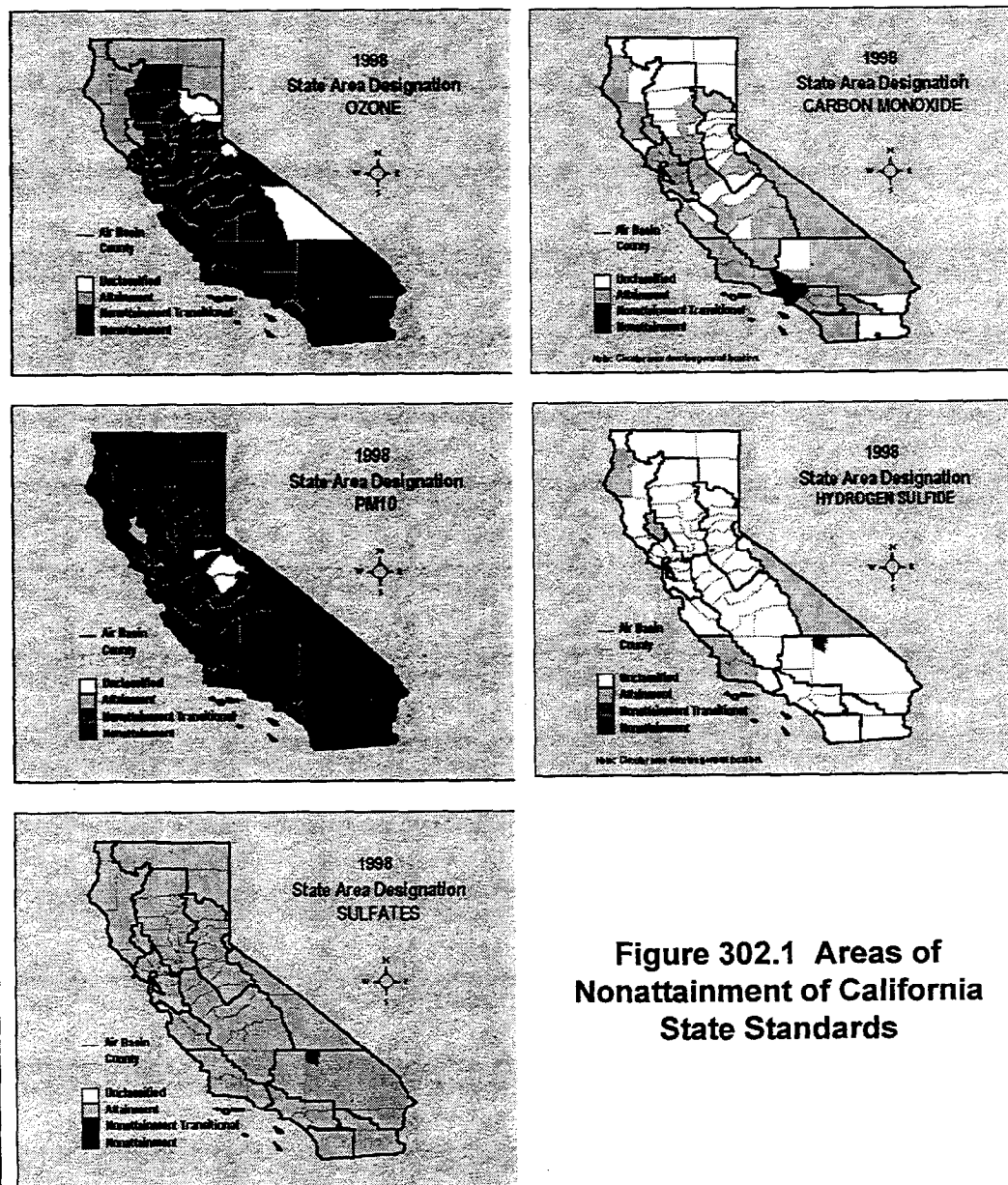
Once the design value has been calculated it can be used to determine the severity classification for an area of carbon monoxide nonattainment.

- Serious - Area has a design value of 16.5 ppm and above
- Moderate - Area has a design value of 9.1 ppm to 16.4 ppm
- Not Classified - An area designated as an carbon monoxide nonattainment are as the date of the 1990 Clean Air Act Amendments and did not have sufficient data to determine if it is meeting or not meeting the CO standard.

302.3 CALIFORNIA NONATTAINMENT AREAS

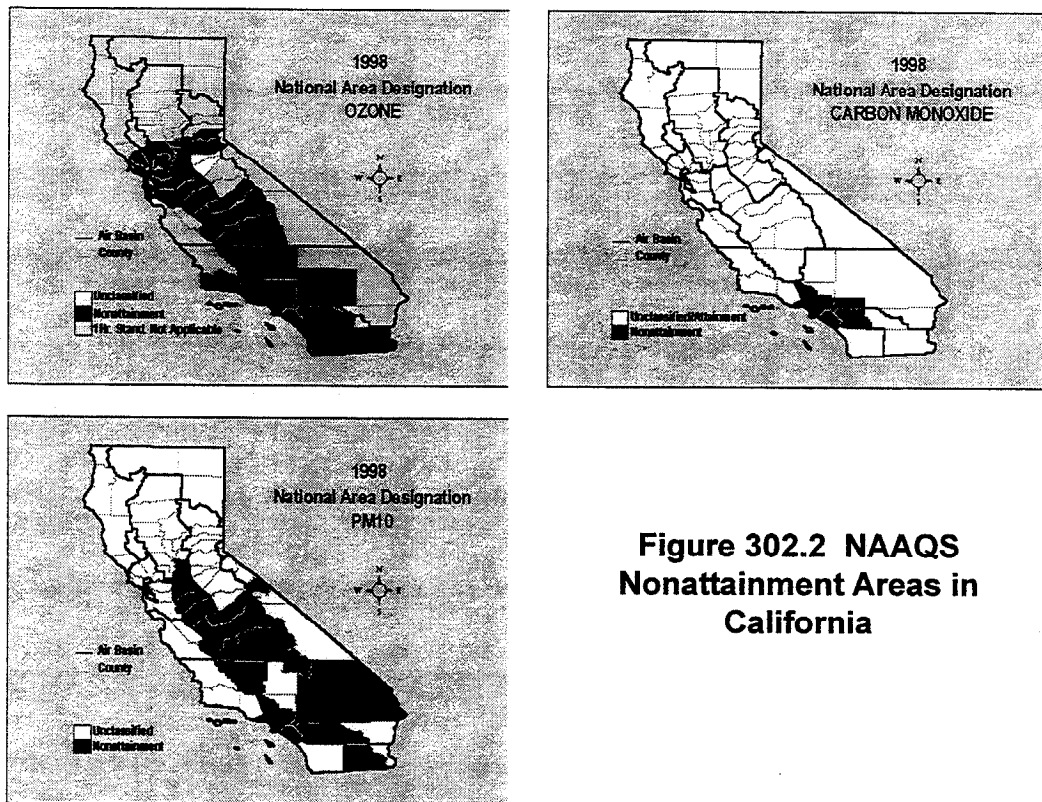
Nonattainment areas for both state (Figure 302.1) federal (NAAQS) (Figure 302.2) ambient air quality standards exist in California. Since the California

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**Figure 302.1 Areas of
Nonattainment of California
State Standards**

standards are more stringent than the national standards, the nonattainment areas for the California standards are more wide spread. In addition, the Mediterranean climate of California and the mountain/valley terrain make ideal conditions for inversions that trap pollutants in valleys. The nearly constant summer sun also makes for good conditions for ozone formation. There are more Federal nonattainment areas in California than any other part of the country.



**Figure 302.2 NAAQS
Nonattainment Areas in
California**

In order to achieve and maintain attainment of the state and federal air quality standards, in addition to the national programs and rules, the California Health and Safety Code requires that the districts make and enforce stationary source and transportation control rules and regulations that will lead to the achievement and maintenance of the standards. The Air Resources Board is also required to review those rules and regulations.

302.4 NATIONAL NONATTAINMENT AREAS

Nationally, nonattainment areas have been established for exceedances of the NAAQS (Figure 302.3). Except for NO_2 , there are exceedances of each of the NAAQS at some place in the country. In 1997 all NO_2 monitoring stations reported attainment of the NAAQS and in July 1998 the EPA announced redesignation of the South Coast Air Basin (the last remaining NO_2 nonattainment area) to attainment.⁷

Taken as a whole, California is the most severely impacted by air pollution with significant portions of the state classified as nonattainment for ozone, CO, and particulate matter. The east coast also has many nonattainment areas.

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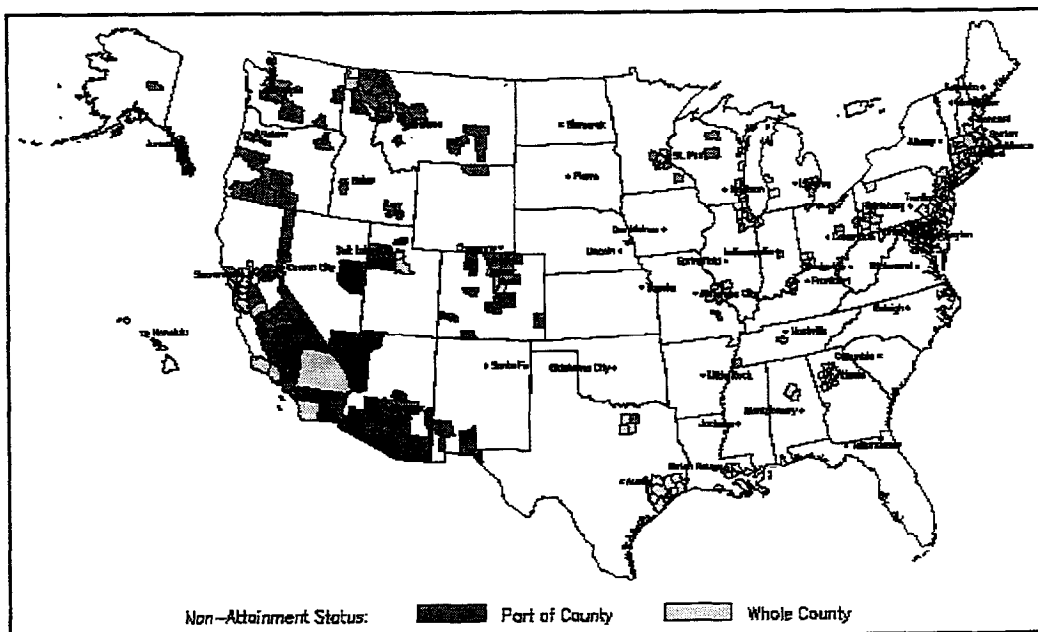


Figure 302.3 Nationwide Locations of Nonattainment Areas for All Criteria Pollutants as of March 1999

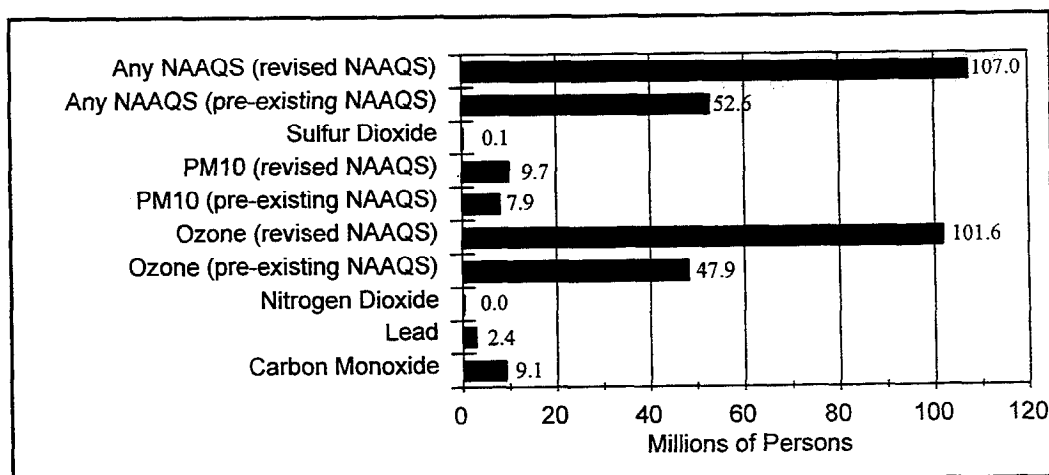


Figure 302.4 Number of Persons Living in Counties With Air Quality Concentrations Above the NAAQS

Reductions in air quality concentrations and emissions have occurred in spite of population and economic growth. Since 1971, the total U.S. population has increased 31%, vehicle miles driven have increased 127%, and the gross domestic product (GDP) has increased 114%.^{Reference 7} During that same period, aggregate emissions of criteria pollutants have decreased by 31%. The most notable reductions have occurred in lead emissions (reduced by 98%), carbon monoxide (reduced by 60%), and sulfur dioxide (reduced by 55%). The only exception to these emission decreases is nitrogen dioxide; which, although the ambient concentration has decreased by 25%, the emissions have increased by 11%. In spite of these improvements, approximately 107 million people in the United States still live in nonattainment areas (Figure 302.4).

303 AEROMETRIC INFORMATION RETRIEVAL SYSTEM - AIR QUALITY SUBSYSTEM (AIRS - AQS)

The Aerometric Information Retrieval System (AIRS) is a computerized database containing information about certain types of airborne pollutants in the United States. The measurements of ambient concentrations of the criteria pollutants, as well as data on air toxics, volatile organic compounds (VOCs), and meteorological data is contained in the Air Quality Subsystem (AQS) of AIRS.

The AIRS-AQS replaced SAROAD (Storage and Retrieval of Aerometric Data), which was implemented after Congress passed the Clean Air Act of 1963. SAROAD contained ambient air quality and meteorological data, including some from the National Air Sampling Network which was established in 1957 as the first nationwide air monitoring system.

The AIRS-AQS database contains data collected at thousands of monitoring stations across the nation operated by the EPA, other Federal agencies, and state and local agencies. The data include the monitoring site descriptions, raw and summary data, and information on the precision and accuracy. The primary monitoring stations that submit data into the AIRS database are the State and Local Air Monitoring Stations (SLAMS) and the National Air Monitoring Stations (NAMS). An additional network, the Photochemical Assessment Monitoring Stations (PAMS), collects data on ozone, nitrogen oxides, and a target list of nearly 60 volatile organic compounds that include ten hazardous air pollutants. The PAMS data are collected in nonattainment areas that are classified as serious, severe, or extreme. Ambient data on any of the 188 air toxics listed in the 1990 Clean Air Act Amendments, or any other air pollutant may

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also be submitted on a voluntary basis by any monitoring organization for inclusion in the database.

304 AIR MONITORING PROGRAMS

In Chapter 100 (Section 101.1) the history of air monitoring was discussed. Although efforts at air monitoring go back over a century, comprehensive monitoring programs did not begin until much more recently.

304.1 FEDERAL AIR MONITORING PROGRAMS

There is an alphabet soup of monitoring programs authorized by the U.S.EPA to monitor for the criteria pollutants as well as toxic air pollutants, volatile organic compounds, meteorological parameters, visibility related parameters, and any other pollutant that the EPA Administrator determines that a nationwide monitoring program is necessary for. For the most part, the monitoring is conducted by state and local air quality agencies. However, if the state or local entity refuses or fails to conduct monitoring to the EPA's satisfaction, the EPA may step in to conduct that monitoring. Sections 304.1.1 through 304.1.5 discuss the various national monitoring programs. In addition, other programs, such as the IMPROVE program for visibility protection, regional programs, and international programs are discussed in succeeding sections. Implementation of monitoring programs in California is discussed in section 304.2.

304.1.1 SLAMS - State and Local Air Monitoring Stations

The State and Local Air Monitoring Stations (SLAMS) network makes up the backbone of air monitoring efforts in the United States. These stations make up the network that is required by the EPA to be included in the State Implementation Plan (SIP). The NAMS (National Air Monitoring Stations) and PAMS (Photochemical Assessment Monitoring Stations) are a subset of the SLAMS network. Many Special Purpose Monitoring Stations (SPMs) and Prevention of Significant Deterioration (PSD) monitoring stations are also part of the SLAMS network; however all SPM and PSD monitors are not necessarily SLAMS, nor do they necessarily meet all SLAMS criteria.

Monitoring stations from which the state will use the data as part of demonstrating attainment/nonattainment or in computing NAAQS design values must meet the SLAMS requirements. Stations from which the data will be used for other SIP-related functions are not necessarily required to meet the SLAMS require-

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ments; although there must be a specific monitoring schedule, procedures, quality assurance procedures, and siting requirements that have been approved by the EPA Regional Administrator.

Except for specific cases, monitoring methods used in a SLAMS must be a reference or equivalent method (see Sections 304.1.6 and 403.1). In those rare occurrences where nonreference/equivalent methods must be used, test data or other information demonstrating the performance of the method must be submitted to the EPA for approval. Likewise, monitoring equipment cannot be modified in a manner that would significantly alter its performance except for temporary modifications (less than four months) if the part to repair a malfunctioning instrument cannot be obtained within 45 days. Unless and until such a temporary modification is approved, the data submitted must be marked as from a temporarily modified method and a report detailing the modifications must accompany the data submission.

There are no criteria for determining the total number of stations in a SLAMS network, except for a minimum number of lead SLAMS. The optimum size of a particular SLAMS network involves trade-offs between the data needs and available physical and fiscal resources. This optimum can be established during the network design process.

As a minimum, there must be at least two lead SLAMS in an urbanized area greater than 500,000 persons. Also, there must be at least two lead monitoring stations in areas that have exceeded the NAAQS in the past eight quarters.

The SLAMS monitoring stations must be located to meet at least four basic monitoring objectives:

- Highest concentrations expected in the area
- Representative concentration in an area of high population density
- Impact of significant sources on ambient concentrations
- General background concentrations

Of these objectives, the most important to measure at if resources do not allow monitoring at four types of sites are the first two - highest concentrations and high population exposure.

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The concept of spatial scale of representativeness helps clarify the link between the monitoring objectives and the physical location of the monitoring station. The goal in siting a monitoring station is to match the spatial scale representativeness of monitoring with the objective of the station or specific monitor. In some cases, monitors of different scales can be located at the same monitoring station. The spatial scale of representativeness is described in terms of the physical dimensions of the air parcel monitored in which the pollutant concentrations are reasonably similar. These scales are:

- Microscale - several meters up to about 100 meters
- Middle Scale - 100 meters up to 500 meters
- Neighborhood Scale - 0.5 km up to 4.0 km
- Urban Scale - 4 km up to 50 km
- Regional Scale - tens of kilometers up to hundreds of kilometers
- National Scale - on a scale of thousands of kilometers
- Global Scale - generally mixed on continental to worldwide scale

Additional information about spatial scales of monitoring is contained in Section 603 of this manual.

The spatial and physical scales of monitoring, intended objectives, and properties and sources of the pollutants being monitored must be integrated when locating a monitoring site (Table 304.1). For example, CO concentration typically peak near roadways and decrease rapidly with distance from the street. In this case a microscale station is called for by the objective of monitoring the highest concentrations and the proximity of the concentration peak to the roadway. Many pedestrians may also be exposed on sidewalks beside the roadway. To determine CO concentrations that are representative of a larger area (for example: concentrations well mixed over an area the size of a typical housing tract) the station siting should meet the neighborhood scale criteria.

When monitoring secondary pollutants, such as ozone, transport, reactions rates, as well as precursor sources must be taken into account when deciding the scale and location of the monitoring stations.

Table 304.1 Relationship of Monitoring Objective and Scale of Representativeness

| Monitoring Objective | Appropriate Siting Scales |
|-----------------------|--|
| Highest Concentration | Micro, Middle, Neighborhood, (sometimes Urban) |
| Population | Neighborhood, Urban |
| Source Impact | Micro, middle, neighborhood |
| General/Background | Neighborhood, Regional |

Open path analyzers can often be used effectively to provide monitoring on neighborhood and larger scales. The inherent areal coverage of the path averaging beam lends itself to larger areawide averages. The monitoring path lengths need to be commensurate with the intended scale of repre-

sentativeness and located carefully with respect to local sources or potential obstructions.

304.1.2 NAMS - National Air Monitoring Stations

The concept of NAMS is to provide data for national policy analyses/trends and for reporting to the public on major metropolitan areas. The NAMS are selected from the SLAMS network (i.e. a subset of the SLAMS) with an emphasis on urban and multisource areas. It is not the intent to monitor every area where the NAAQS are violated; the data from SLAMS are designed to be the primarily nonattainment decision process data.

Generally, a larger number of NAMS is required in more polluted urban areas and areas with more multisource diversity. The primary objective of NAMS is to monitor in areas where the pollutant concentration and the population exposure are expected to be greatest consistent with the averaging time of the NAAQS. The NAMS fall into two categories whose monitoring scale should be consistent with the purpose of the station (Table 304.2):

- Category (a): Stations located in area(s) of expected maximum concentrations.
- Category (b): Stations which combine poor air quality with high population exposure, but are not necessarily located in areas of the expected maximum pollutant concentrations. Category (b) monitors would generally represent larger spatial scales than Category (a) monitors.

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For each urban area where NAMS are required, both categories of monitoring must be established. In the case of SO₂ and TSP, if only one NAMS is needed, then Category (a) must be used. The analysis of NAMS data must consider the distinction between the category types as appropriate.

304.1.3 PAMS - Photochemical Assessment Monitoring Stations

The PAMS network was required by the 1990 Clean Air Act Amendments in order to obtain more comprehensive and representative data on ozone air pollution. The network monitors for ozone, oxides of nitrogen, and VOC in ozone nonattainment areas classified as serious, severe, or extreme. In addition to providing data related to determining attainment of the NAAQS, data from the PAMS network is applicable to SIP control strategy development and evaluation, corroboration of emissions tracking, appraisals of pollutant trends, and exposure assessment.

The PAMS network is based on selection of an array of monitoring locations relative to ozone precursor source areas and the predominant wind direction associated with high ozone events. Each location in the array is associated with a specific objective: characterization of precursor emissions (total and speciated VOC and oxides of nitrogen), transport of precursor compounds into and out of the monitored urban area, transport of ozone into and out of the monitored urban area. The speciated VOC also forms an initial urban toxic air pollutant database.

A set of up to five stations makes up the PAMS array required in an affected nonattainment area. Specific monitoring objectives are associated with each station in the array using four distinct site types:

Table 304.2 Scale of NAMS Stations

| Category | Pollutant | Scale |
|--------------|--|------------------------|
| Category (a) | CO | Microscale |
| | Lead | Micro- or Middle Scale |
| | PM ₁₀ | Micro- or Middle Scale |
| | SO ₂ | Neighborhood Scale |
| | NO ₂ | Neighborhood Scale |
| | Ozone | Urban Scale |
| Category (b) | CO, Lead, PM ₁₀ , SO ₂ , Ozone | Neighborhood Scale |
| | NO ₂ | Urban Scale |

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Type 1 - Sites that monitor upwind background and transported ozone and precursor concentrations entering the subject area. Type 1 sites are located in the predominant morning upwind direction from the local area of maximum ozone precursor emissions during the ozone season at a distance that allows the station to be classified as an urban scale monitoring station. Data from Type 1 stations is used principally for:

- Future development and evaluation of control strategies;
- Identification of incoming pollutants;
- Corroboration of NO_x and VOC emission inventories;
- Establishment of boundary conditions for future photochemical grid modeling and mid-course control strategy changes; and
- Development of incoming pollutant trends

Type 2 - Sites located immediately downwind (in the most common wind direction) of the area of maximum precursor emissions. These sites are established to monitor the magnitude and type of precursor emissions in the area of the expected impact of the maximum precursor emissions. These stations are typically placed near the downwind boundary of the central business district and situated such that they meet the requirements for neighborhood scale monitoring. Depending on the size of the area, a second Type 2 station may be needed. If needed, the second Type 2 station should be placed in the second most predominant morning wind direction. Data from Type 2 monitoring stations is used for:

- Development and evaluation of imminent and future control strategies;
- Corroboration of NO_x and VOC emission inventories;
- Augmentation of RFP tracking;
- Verification of photochemical grid model performance;
- Characterization of ozone and toxic air pollutant exposures;

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- Development of pollutant trends, particularly toxic air pollutants and annual ambient speciated VOC trends to compare with trends in annual VOC emission estimates; and
- Determination of attainment with the NAAQS for NO₂ and ozone.

Type 3 - Sites located downwind from the area of maximum precursor emissions. Type 3 stations are intended to monitor maximum ozone concentrations and are typically 10 to 30 miles downwind from the fringe of the urban area. The downwind direction should be determined from historical wind data of the afternoon winds occurring during the period of 1:00 pm to 4:00 pm on high ozone days (or days of potentially high ozone). These stations should be located so that they satisfy the siting requirements of urban scale monitoring stations. Data from Type 3 PAMS monitoring stations is used for:

- Determination of attainment with the NAAQS for ozone;
- Evaluation of future photochemical grid modeling applications;
- Future development and evaluation of control strategies;
- Development of pollutant trends; and
- Characterization of ozone pollutant exposures.

Type 4 - These sites are established to characterize the extreme downwind transported ozone and precursor concentrations exiting the study area. These stations will identify those areas which are potentially contributing to overwhelming transport in other areas. Type 4 sites are located in the predominant afternoon downwind direction, as determined for a Type 3 site and are located such that they satisfy the siting requirements of an urban scale monitoring station. Data from these monitoring stations is used for:

- Development and evaluation of ozone control strategies;
- Identification of emission and photochemical products leaving the area;
- Establishment of boundary conditions for photochemical grid modeling;
- Development of pollutant trends;

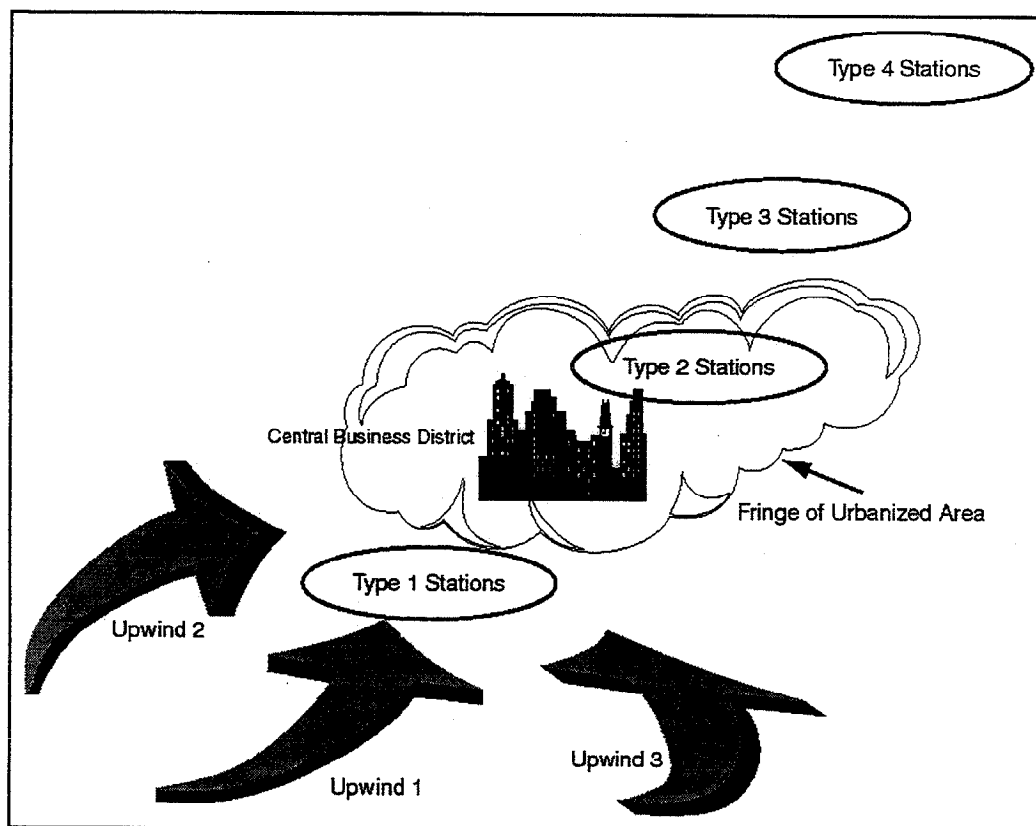


Figure 304.1 Layout of an Isolated Area PAMS Network. Upwind 1 and 2 Represent the First and Second Most Predominant High Ozone Day Morning Wind Directions. Upwind 3 Represents the High Ozone Day Afternoon Wind Direction.

- Background and upwind information for other downwind areas; and
- Evaluation of photochemical grid model performance.

The PAMS monitoring stations may be arrayed around a single urban area (Figure 304.1) or multiple urban areas (Figure 304.2). When arrayed around multiple urban areas, the monitoring stations may function as more than one type of station. For example: a station may serve as a Type 3 (downwind) station for one urban area and as a Type 1 (upwind) station for an urban area downwind of the first area.

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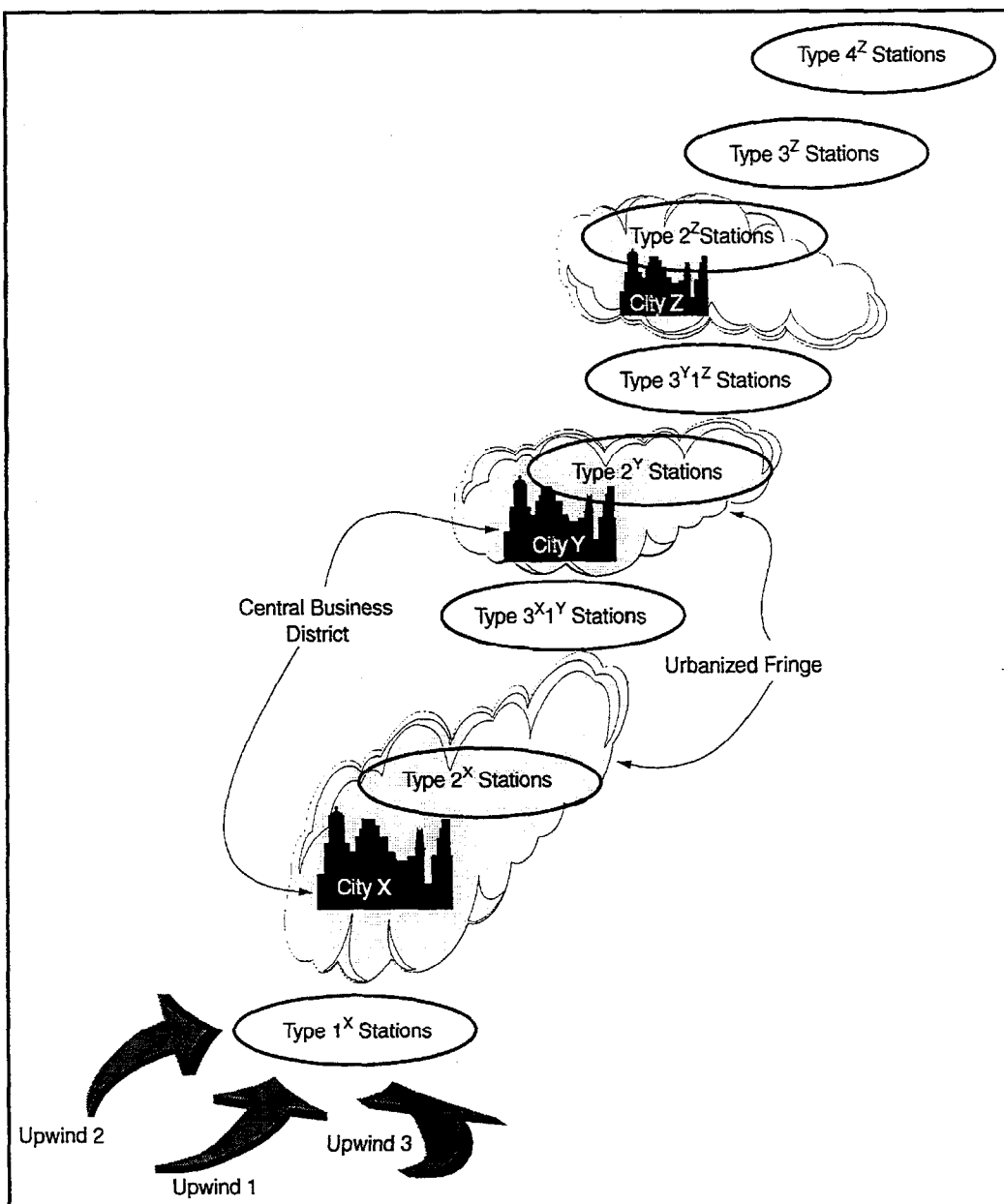


Figure 304.2 Layout of Multi-Area and Transport Area PAMS Network.

Upwind 1 and 2 Represent the First and Second Most Predominant High Ozone Day Morning Wind Directions. Upwind 3 Represents the High Ozone Day Afternoon Wind Direction. Superscripts Refer to the Type and City a Monitoring Station Pertains to (i.e. Type 3^{X1^Y} Stations Means the Station Serves as a Type 3 Station for City X and a Type 1 Station for City Y).

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Table 304.3 PAMS Network Sampling Frequency Categories

| Frequency Category | Three Hour Samples | | 24 Hour Samples | |
|--------------------|--------------------|--|-----------------|--|
| | Number | Frequency | Number | Frequency |
| A | 8 | Every third Day During the Monitoring Period | 1 | Every Sixth Day During the Monitoring Period |
| B | 8 | Every Day During the Monitoring Period | 1 | Every Sixth Day, Year Round |
| C | 8 | Five Peak Ozone Days Plus the Day Before | 1 | Every Sixth Day During the Monitoring Period |
| | 8 | Every Sixth Day During the Monitoring Period | | |
| D | 8 | Every Third Day During the Monitoring Period | NA | |
| E | 8 | Every Day During the Monitoring Period | NA | |
| F | 8 | Five Peak Ozone Days Plus the Day Before | NA | |
| | 8 | Every Sixth Day During the Monitoring Period | | |

Since PAMS is oriented toward monitoring of ozone and its precursors, year-round sampling is not necessary. Monitoring for precursor substances must be conducted during June through August; however monitoring throughout the entire ozone season is preferred. The minimum PAMS ozone monitoring must adhere to the SLAMS ozone season. The SLAMS ozone season (40CFR58 Appendix D, Section 2.5) lasts from a few months in summer to year-round depending on the state.

Table 304.4 PAMS Network Minimum Monitoring Network Requirements

| Population of MSA/CMSA or Nonattainment Area (whichever is larger) | Required Site Type | Minimum Speciated VOC Sampling Frequency | Minimum Carbonyl Sampling Frequency |
|--|--------------------|--|-------------------------------------|
| Less Than 0.5 Million | Type 1 | A or C | |
| | Type 2 | A or C | D or F |
| 0.5 to 1.0 Million | Type 1 | A or C | |
| | Type 2 | B | E |
| | Type 3 | A or C | |
| 1.0 to 2.0 Million | Type 1 | A or C | |
| | Type 2 | B | E |
| | Type 2 | B | E |
| | Type 3 | A or C | |
| More Than 2.0 Million | Type 1 | A or C | |
| | Type 2 | B | E |
| | Type 2 | B | E |
| | Type 3 | A or C | |
| | Type 4 | A or C | |

While ozone and NO^x monitoring should be continuous, speciated VOC and carbonyl sampling consists of 3 hour and 24 hour samples. The number and frequency of VOC and carbonyl samples depends on the size of the monitored area (Table 304.3 and Table 304.4).

The minimum required number and type of

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PAMS monitoring sites and sampling requirements are based on the population of the urban area or nonattainment area (whichever is larger). Often for the network to adequately characterize the ambient air quality of an urban or nonattainment area, it must extend beyond the boundary of the area.

Various sampling requirements pertain to areas of increasing size (Table 304.4) to accommodate the impact of transport on the smaller urban areas, to account for the spatial variations inherent in large areas, to satisfy the differing data needs of large versus small areas due to the intractability of the ozone nonattainment problem, and to recognize the potential economic impact of implementation of PAMS on state and local budgets.

Frequency categories C and F require sampling on the day of peak ozone concentration and the previous day. This requires the development of a means of forecasting those peak days. The scheme for forecasting the peak ozone days should be included as part of the PAMS plan submitted for approval and should be reviewed during each required annual review of the SLAMS network.

In order to support the PAMS monitoring objectives associated with the need for the various air quality analyses, model inputs, and model performance evaluations, meteorological monitoring is required at each PAMS site. Meteorological monitoring must include wind measurements at 10 meters above the ground and upper air meteorological monitoring. The upper air monitoring site may be located separately from the Type 1 through 4 sites, but must be representative of the upper air data in the nonattainment area.

304.1.4 PSD - Prevention of Significant Deterioration

Whereas PAMS monitoring applies to nonattainment areas, monitoring associated with the PSD program applies to permits for new major sources or major modifications to stationary sources in attainment or unclassified areas. Under PSD the construction of certain new major stationary sources and major modifications are subject to a preconstruction review which includes an ambient air quality analysis and may require postconstruction ambient monitoring. If suitable air quality data exists, that data may be used for the preconstruction analysis. If it doesn't exist, ambient monitoring may be required before the construction permit may be issued.

For SO₂, CO, and NO₂ continuous air quality monitoring data must, in general, be used to establish the preconstruction ambient air quality in the vicinity of the

proposed facility. For VOC, continuous ozone monitoring data must be used; and the 24-hour manual method used for PM_{10} and lead. However, no preconstruction monitoring data will generally be required if the ambient air quality concentrations before construction are less than the significant monitoring concentrations

Table 304.5 Significant Monitoring Concentrations⁹

| Pollutant | Air Quality Concentration ($\mu\text{g}/\text{m}^3$) and Averaging Time |
|--|---|
| Carbon Monoxide | 575 (8 Hour) |
| Nitrogen Dioxide | 14 (Annual) |
| Sulfur Dioxide | 13 (24 Hour) |
| Particulate Matter (TSP) | 10 (24 Hour) |
| Particulate Matter (PM_{10}) | 10 (24 Hour) |
| Ozone | (a) |
| Lead | 0.1 (3 Month) |
| Asbestos | (b) |
| Beryllium | 0.001 (24 Hour) |
| Mercury | 0.25 (24 Hour) |
| Vinyl Chloride | 15 (24 Hour) |
| Fluorides | 0.25 (24 Hour) |
| Sulfuric Acid Mist | (b) |
| Total Reduced Sulfur (Including H_2S) | 10 (1 Hour) |
| Reduced Sulfur (Including H_2S) | 10 (1 Hour) |
| Hydrogen Sulfide | 0.2 (1 Hour) |

a. No specific air quality concentration for ozone is prescribed. Exemptions are granted when a source's VOC emissions are <100 tons per year.

b. No acceptable monitoring techniques are available at this time. Therefore, monitoring is not required until acceptable techniques are available.

ing concentrations (Table 304.5).⁹ Below the significant monitoring concentration levels measurement errors dominate the values, making their use questionable.

Cases where the projected impact of the source or modification is less than the significant monitoring concentration are also exempt from the preconstruction monitoring requirement, consistent with the de minimis concept. The exception to the de minimis exemption occurs when a proposed source of modification would adversely impact on a Class I area or would pose a threat to the remaining allowable increment or NAAQS.

The EPA has discretion in requiring

postconstruction monitoring. In most cases they do not require monitoring. However, if there are valid reasons for the data, postconstruction monitoring may be required. Generally, postconstruction monitoring is only required of large sources or sources whose impact may threaten the NAAQS or the PSD increment. Postconstruction monitoring may also be required if such factors as

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complex terrain, fugitive emissions, and other uncertainties in source or emission characteristics result in significant uncertainties about the projected impact of the new source or modification. In this case the postconstruction monitoring is needed to assess the emission model performance.

Pre- and postconstruction monitoring may also be required of sources of noncriteria pollutants; however, modeling is the preferred analysis tool for noncriteria pollutants.

304.1.5 SPMS - Special Purpose Monitoring Stations

Special purpose monitoring stations (SPMS) is a generic term used for all monitors other than SLAMS, NAMS, PAMS, and PSD monitors included in an agency's monitoring plan or for monitors used in special studies whose data are officially reported to the EPA. Any SPMS which records a violation of the NAAQS must be seriously considered as a potential SLAMS site during the annual SLAMS network review.¹⁰

Special purpose monitoring stations are used as a tool to supplement the ambient air monitoring network to obtain information on where to locate permanent monitoring stations, to provide additional data in support of pollutant formation and transport analyses, or to assess air quality in a particular location. Industries often operate special purpose monitoring in support of the PSD program and to satisfy their own information needs on air quality around their facilities. Special purpose monitoring studies vary in duration from temporary sites needed only during a portion of the year to long-term air pollution studies over large areas. Examples of long-term SPMS are the CASTNet (Clean Air Status and Trends Network) and IMPROVE (Interagency Monitoring of Protected Visual Environments).

Special purpose monitoring fills a need to look beyond the minimal SLAMS network and provides a flexible monitoring program. An SPMS is not required to use reference or equivalent methods, nor is the data required to be submitted to the EPA. However, an SPMS monitor from which the state intends to use the data as part of demonstration of attainment or nonattainment or in computing a design value for control purposes of the NAAQS must meet the requirements for SLAMS. For use in any other SIP-related purposes, although not required to meet the SLAMS requirements, the SPMS must be operated in accordance with a monitoring schedule, methodology, quality assurance procedures, and probe or instrument siting specifications approved by the EPA Regional Administrator.

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The U.S.EPA is obligated under current regulations to consider all publicly available, valid (collected in accordance with 40CFR58), and relevant data in the NAAQS regulatory process. This includes data available through AIRS and data available through other sources including SPMS operated by third parties. Reasonable means should be employed to obtain and verify these non-AIRS data.

304.2 CALIFORNIA AIR MONITORING PROGRAMS

Section 39607 of the California Health and Safety Code calls for establishment of an ambient air quality monitoring program. This program implements the SLAMS, NAMS, PAMS, PSD, and SPMS required by the federal Clean Air Act; although the ARB has set ambient air quality standards for California that are more stringent than the federal standards. The SLAMS, NAMS, PAMS, and SPMS in California are operated by the Air Resources Board, local Air Pollution Control Districts/Air Quality Management Districts, private contractors, and by the National Park Service. These entities operate more than 250 air monitoring stations throughout California. A few monitoring stations are located in Mexico (Tijuana, Mexicali, and Rosarito Playas) and operated by a contractor for the ARB.

For data to be considered data-of-record for both California and EPA purposes, the collection must follow both EPA and ARB criteria. In general, ARB monitoring protocols mirror those of the EPA. However, this is not always the case. For example, the tapered element oscillating microbalance (TEOM), beta attenuation method (BAM), and dichotomous samplers are considered to be reference or equivalent methods for particulate matter collection by the EPA, but not by the ARB (see sections 403.1 and 403.2 of this manual). Thus data collected by these methods would be acceptable to the U.S.EPA for determination of attainment of the NAAQS. However, it would not be acceptable to the ARB for determination of the CAAQS.

304.3 OTHER AIR MONITORING PROGRAMS

In addition to the air monitoring programs specified and operated by the EPA and the various states, there are many other programs. These other programs include such things as regional programs, purpose driven programs, foreign national programs, and international programs.

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304.3.1 IMPROVE

The IMPROVE (Interagency Monitoring of Protected Visual Environments) is a cooperative monitoring program for monitoring visibility in Class I areas.¹¹ The IMPROVE program is one of the few that has an extensive background of PM_{2.5} data. The IMPROVE PM_{2.5} data set goes back to 1987. The IMPROVE program is designed to:

- Establish the current background aerosol concentrations in mandatory Class I areas;
- Identify chemical species and emission sources responsible for existing anthropogenic visibility impairment;
- Document long-term trends; and
- Provide regional haze monitoring in Class I areas.

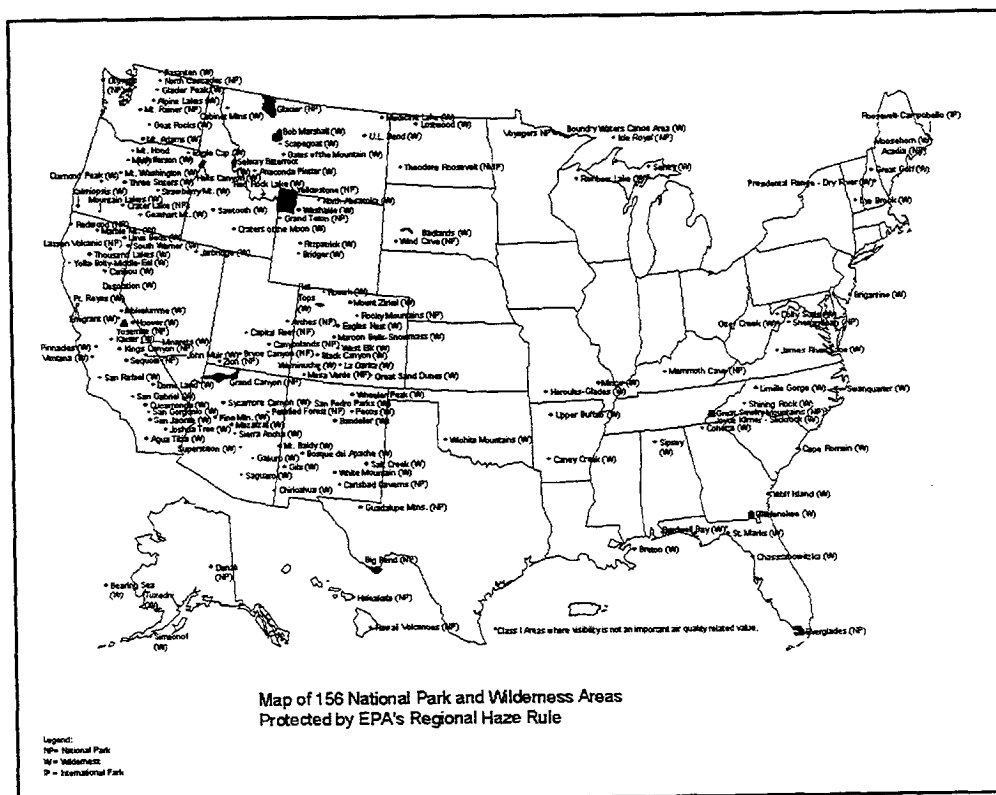


Figure 304.3 Class One Areas¹¹

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The 156 mandatory Class I areas (Figure 304.3) in the United States have been combined into 108 clusters on the basis of elevation and separation (within 100 km of each other). At least one IMPROVE site either currently exists in each cluster, or will be located in the cluster in the near future. The IMPROVE network is primarily designed to monitor regional visibility and regional hazes, therefore the site must be regional scale (although the IMPROVE protocol does not strictly follow the 40 CFR 58 siting parameters).

The IMPROVE program is coordinated by the IMPROVE Steering Committee consisting of representatives from: the Environmental Protection Agency, the four Federal Land Managers (FLMs: National Park Service, Forest Service, Fish and Wildlife Service, and Bureau of Land Management) and four interstate agencies (State and Territorial Air Pollution Program Administrators/Association of local Air Pollution Control Officials, Western States Air Resources Council, Northeast States for Coordinated Air Use Management, Mid-Atlantic Regional Air Management Association). Crocker Nuclear Laboratory at the University of California, Davis has been the contractor for aerosol monitoring since the program began in 1987.

The IMPROVE sampler is designed to obtain a complete signature of the composition of airborne particulate matter affecting visibility. Fine particles ($PM_{2.5}$) are collected on a Teflon filter for mass, optical absorption, and elemental

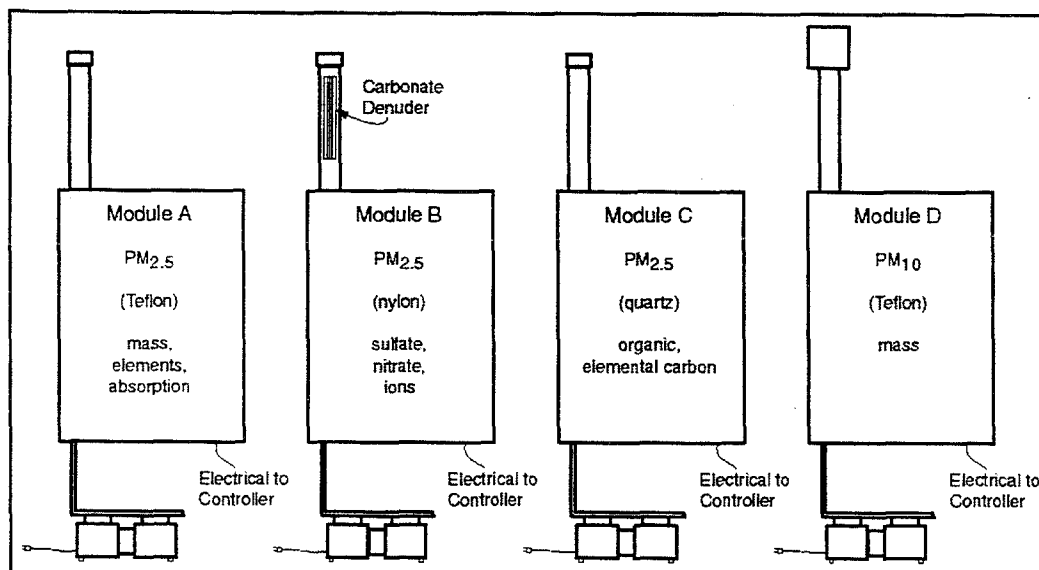


Figure 304.4 Diagram of the IMPROVE Aerosol Sampler

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content (H, Na - Pb); a nylon filter for nitrate, sulfate, and chloride; and quartz filters for organic and elemental carbon. Coarse particles (PM_{10}) are collected on Teflon filters for mass determination.

An IMPROVE sampling site consists of four sampling modules (Figure 304.4) and a controller module. The modules are usually housed in a small shelter to protect them from precipitation and wind. The shelter also protects the operator during the weekly sample changes. Each $PM_{2.5}$ module contains a cyclone to separate particles larger than $2.5\ \mu m$, solenoids, a critical orifice flow controller, flow gauges, an inlet stack, and associated electronics. Module B contains a denuder in the inlet stack to remove nitric acid vapor. In Module D the inlet and cyclone are replaced by a commercial PM_{10} inlet. To avoid removal of the coarser particles, the airstream goes vertically straight to the filters.

As of December 1999, the sampling frequency in the IMPROVE network will be one-day-in-three; previously the IMPROVE protocol had been twice per week.

304.3.2 Regional Programs

In several parts of the country groups of states have gotten together to coordinate their air pollution efforts. For example, NESCAUM (Northeast States for Coordinated Air Use Management). NESCAUM is made up of the six New England states plus New York, and New Jersey (Figure 304.5).

NESCAUM's primary purpose is to exchange technical information and to promote cooperation and coordination of technical information among the member states. Regional air flow patterns transport air pollutants into the NESCAUM states; coordination of monitoring programs, therefore, benefits all states in the

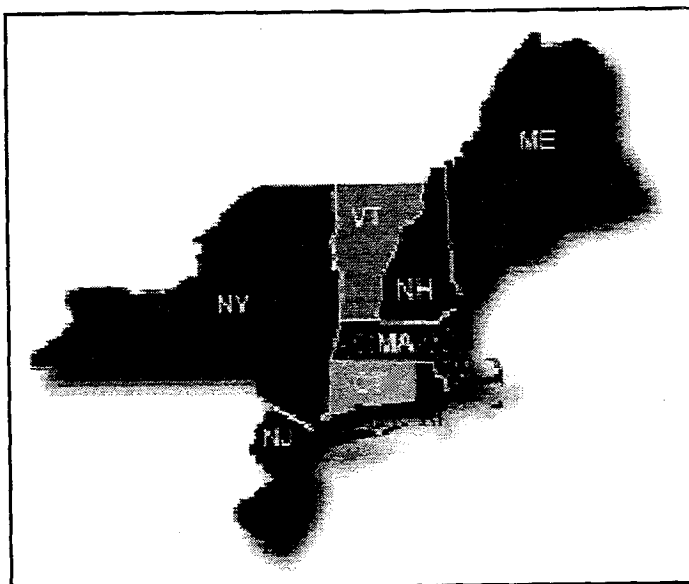


Figure 304.5 NESCAUM States

program. NESCAUM sponsors some regional scale monitoring as well as coordinating ambient air monitoring in the member states.

304.3.3 GEMS/AIR

The Global Environmental Monitoring System for Air Pollution (GEMS/Air) is an urban air pollution monitoring and assessment program coordinated by the World Health Organization (WHO) and the United Nations Environmental Programme (UNEP).¹² It is now a part of WHO's Air Management Information Systems (AMIS). The focus of the program is on improving air quality data and emission inventories in developing countries, ultimately leading to setting appropriate health standards and developing national plans for air quality improvement. Since funding is often limited in developing countries, WHO has established a "twinning concept" of matching air pollution agencies in Europe and the United States with those developing countries needing assistance. In the twinning concept, a donor agency provides used monitoring equipment and technical expertise to a sister city or country. Although the donated equipment may not be state-of-the-art, it is operational and provides an improved monitoring capability for the recipient agency. Thus leading to improved understanding of the worldwide impacts of air pollution on public health and natural resources.

As noted, the GEMS/Air program is part of the AMIS. The AMIS has the objective of transferring information on air pollutant concentrations and air quality management tools among countries. In this context, AMIS acts as a global information exchange system; i.e.:

- Coordinating databases with information on air quality issues in major cities and megacities;
- Acting as an information broker between countries;
- Providing and widely distributing technical documents on air quality monitoring and management;
- Publishing and widely distributing annual trend reviews on air pollutant concentrations;
- Giving training courses with respect to air quality monitoring and management;

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- Linking donors and needy recipients for monitoring equipment;
- Running Regional Collaborative Centers to support data transfer activities, perform training courses, and carrying out twinning projects.

There are expected to be approximately 300 contributing cities in the system by the year 2000. The program monitors ozone, NO_x, CO, SO₂, lead, and particulate matter.

304.3.4 International Programs

Most developed industrial nations around the world have air monitoring programs. These programs may or may not be similar to the programs in the United States. Many programs are accessible online via Internet connections. An English web site (<http://www.aeat.co.uk/netcen/airqual/networks/aqlinks.html>) provides a number of links to air quality monitoring around the world.

305 STATIONARY SOURCE PERMITS REQUIRING AMBIENT AIR MONITORING

Occasionally a permit issued for the construction/operation of a stationary source will require that ambient air monitoring be conducted. This is particularly true if the source is under the PSD program. However, any permit may require monitoring if the issuing agency feels that there is a need for ambient data before or after construction of the source.

306 AIR POLLUTION EPISODES

An air pollution episode is the term used for a period of poor air quality, lasting up to several days, often extending over a large geographical area. Concentrations of pollutants may increase singly or the concentrations of several pollutants may increase simultaneously.

Episodes may be caused in different ways: During the winter months, cold stable weather conditions can trap pollutants close to their sources and prevent their dispersion. In California the winter episodes typically include high carbon monoxide and particulate matter concentrations.

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During the summer, a completely different type of episode occurs. These episodes typically occur under high pressure meteorological conditions; which generally are clear, sunny, and have calm winds. These conditions are ideal for the formation of ozone. Other pollutants, particularly particulate matter also frequently build up under these conditions.

306.1 AIR QUALITY INDEX REPORTING

Reporting an Air Quality Index to the public is designed to alert the public to the level of air pollution in the ambient air.¹³ This reporting is especially important during episodes when the public should take precautions to prevent the occurrence of health effects. The Air Quality Index (abbreviated AQI, often referred to as the PSI, short for the older Pollutant Standards Index) is a tool for making the pollutant levels understandable by the general public. The AQI normalizes the concentrations of five criteria pollutants (ozone, CO, particulate matter, SO₂, and NO₂) into equal scale subindexes. The scale of the index is divided into general categories that are associated with health effects.

Table 306.1 AQI Categories, Descriptors, and Colors¹³

| AQI Value | Descriptor | Color | Alert Stage | Advised Precautions (Ozone Sub-Index) |
|------------|-----------------------------------|--------|---|--|
| 0 to 50 | Good | Green | none | |
| 51 to 100 | Moderate | Yellow | 100 = National Ambient Air Quality Standard | Unusually sensitive people should consider limiting prolonged outdoor exertion. |
| 101 to 150 | Unhealthy for Sensitive Groups | Orange | 138 = Health Advisory - Athletes should avoid strenuous outdoor activities | Active children and adults, and people with respiratory diseases, such as asthma, should limit prolonged outdoor exertion. |
| 151 to 199 | Unhealthy | Red | | Active children and adults, and people with respiratory diseases, such as asthma, should avoid outdoor exertion; everyone else, especially children, should limit prolonged outdoor exertion. |
| 200 to 299 | Very Unhealthy | Purple | 200 = Stage I Alert - Everyone should avoid strenuous outdoor activities 275 = Stage II Alert - Everyone should remain indoors | Active children and adults, and people with respiratory diseases, such as asthma, should avoid all outdoor exertion; everyone else, especially children, should limit outdoor exertion. |
| 300 to 500 | Hazardous | Maroon | | |

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306.1.1 AQI Reports

Each urban area (metropolitan statistical area [MSA]) with a population greater than 350,000 must calculate and report the AQI daily. Since pollutants are often transported or form through photochemistry downwind of the source area, a AQI report may apply to neighboring areas when air quality problems exist. Apart from this case, a AQI applies only to the specific MSA for which it has been issued. However, if different AQI categories apply to different definable parts of an MSA, then a separate AQI should be reported for each part of the MSA.

- To assure consistent public notification, a AQI report must contain certain information:
- The reporting area(s) (the MSA or subdivision of the MSA);
- The reporting period (the day for which the AQI is reported);
- The critical pollutant (the pollutant with the highest index value);
- The AQI value (the highest index value; and

Table 306.2 Breakpoints for AQI Calculations

| Breakpoints | | | | | | | AQI | Category |
|---|------------------------------------|--|---|-----------|-----------------------|-----------------------|---------|-----------------------------------|
| Ozone (ppm) 8-hour | Ozone (ppm) 1-hour ¹ | PM ₁₀ (µg/m ³) | PM _{2.5} (µg/m ³) | CO (ppm) | SO ₂ (ppm) | NO ₂ (ppm) | | |
| 0.000-0.069 | - | 0-54 | 0.0-15.4 | 0.0-4.4 | 0.000-0.034 | (²) | 0-50 | Good |
| 0.070-0.084 | - | 55-154 | 15.5-65.4 | 4.5-9.4 | 0.035-0.144 | (²) | 51-100 | Moderate |
| 0.085-0.104 | 0.125-0.164 | 155-254 | 65.5-100.4 | 9.5-12.4 | 0.145-0.224 | (²) | 101-150 | Unhealthy for sensitive groups |
| 0.105-0.124 | 0.165-0.204 | 255-354 | 100.5-150.4 | 12.5-15.4 | 0.225-0.304 | (²) | 151-200 | Unhealthy |
| 0.125-0.374 (0.155-0.404) ^{3,4} | 0.205-0.404 | 355-424 | 150.5-250.4 | 15.5-30.4 | 0.305-0.604 | 0.65-1.24 | 201-300 | Very unhealthy |
| (²) | 0.405-0.504 | 425-504 | 250.5-350.4 | 30.5-40.4 | 0.605-0.804 | 1.25-1.64 | 301-400 | |
| (²) | 0.505-0.604 | 505-604 | 350.5-500.4 | 40.5-50.4 | 0.805-1.004 | 1.65-2.04 | 401-500 | Hazardous |

¹ Areas are required to report the AQI based on 8-hour ozone values. However, there are areas where a AQI based on 1-hour ozone values would be more protective. In these cases, the index for both the 8-hour and the 1-hour ozone values may be calculated and the maximum AQI reported.

² NO₂ has no short-term NAAQS and can generate an AQI only above an AQI value of 200.

³ 8-hour ozone values do not define higher AQI values (≥301). AQI values of 301 or higher are calculated with 1-hour ozone concentrations.

⁴ The numbers in parentheses are associated 1-hour values to be used in this overlapping category only.

- The category descriptor and if reported in a color format, the associated color. Only the specified colors should be used (Table 306.1).

The AQI report may also contain additional information when appropriate:

- The name and index value for other pollutants, particularly those with an index value greater than 100;
- The index values for sub-areas of the reporting area;
- Actual pollutant concentrations; and
- Causes for unusual AQI values.

The AQI must be reported at least five days per week. However, if the index for a pollutant remains under 50 for a season of the year it may be excluded from further calculations for that season. If the AQI remains below 50 for a year, reporting is discretionary.

306.1.2 AQI Calculation

For each pollutant, the AQI transforms the ambient concentration to a scale from 0 to 500. The NAAQS is always an index value of 100. An index value of 50 corresponds to the annual standard if one exists. Higher categories of the index are based on increasingly more serious health effects and increasing proportions of the population that are affected.

The index value is calculated by linear interpolation of the concentration between index breakpoints (Table 306.2). An index value is calculated for each pollutant and the reported AQI corresponds to the highest value. The pollutant giving that value is termed the "critical pollutant". The AQI for particulate matter is only calculated for days on which particulate sampling occurs, although particulate measurements from non-reference or equivalent methods may be used on additional days if that method can be related through linear regression (Equation 306.1) to the reference or equivalent method measurements.

$$I_p = \frac{I_{Hi} - I_{Lo}}{BP_{Hi} - BP_{Lo}} (C_p - BP_{Lo}) + I_{Lo} \quad \text{Equation 306.1}$$

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For example:

Calculating the AQI for ozone (8-hour concentration of 0.130 ppm) gives a value of 203.

$$\frac{300 - 201}{0.375 - 0.125}(0.130 - 0.125) + 201 = 203$$

Similarly calculated, 210 $\mu\text{g}/\text{m}^3$ PM_{10} , 127 $\mu\text{g}/\text{m}^3$ $\text{PM}_{2.5}$, 13.3 ppm CO, and 0.156 ppm 1-hour ozone give AQI values of 128, 177, 165, and 140, respectively. Since the 8-hour ozone is the highest value that is the value reported as the AQI.

The calculated AQI values are then disseminated through television, radio, etc. to notify the public of the air pollution conditions and what, if any, health precautions (Table 306.1) they should take. The Sacramento Valley Spare The Air program (www.sparetheair.com) calculates and publicizes the AQI. In addition to the usual media outlets, the Spare The Air program maintains an e-alert service in which subscribers are sent e-mail notifications when pollutant concentrations (AQI values) reach unhealthy conditions. This can be very handy for sensitive persons.

307 AIR POLLUTION EMERGENCIES

Emergency air pollution monitoring may be conducted in response to industrial accidents, fires, and other unforeseen events. For example: in October, 1997 the ARB Compliance Division conducted monitoring for styrene and total hydrocarbons when a truck carrying catalyzed liquid styrene resin threatened to leak styrene and undergo uncontrolled exothermic polymerization. The resin was repackaged and reloaded on the refrigerated truck before being allowed to proceed.

In another incident, the ARB also conducted monitoring for solvents and toxics after Lake Davis, in Northern California, was poisoned to eradicate Northern Pike in the lake in October, 1997.

308 REFERENCES

1. U.S.EPA, National Ambient Air Quality Standards, 40 CFR 50.

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2. Controversial New Ozone and Particulate NAAWS Issued, 1997, *The Air Pollution Consultant*.
3. Bohm, M., B. McCune, and T. Vandetta, 1991, Diurnal Curves of Tropospheric Ozone in the Western United States, *Atmospheric Environment*, 25A:1577.
4. Cahill, T.A., 1989, *Monitoring of Atmospheric Particulates and Ozone in Sequoia National Park: 1985-1987*, California Air Resources Board Final Report, AS-180-32.
5. Laxton, W. G., 1990, Memo: *Ozone and Carbon Monoxide Design Value Calculations*, U.S.EPA.
6. U.S.EPA, 1994, *Guideline of the Identification and Handling of Ambient Air Quality Data Affected by Special Events or Special Conditions*, EPA-454/D-94-001.
7. U.S.EPA, 1998, *National Air Quality and Emissions Trends Report*, 1997, EPA/R-98-016, <http://www.epa.gov/oar/aqtrnd97/>.
8. U.S.EPA, 1987, *Ambient Monitoring Guidelines for Prevention of Significant Deterioration (PSD)*, EPA-450/4-87-007.
9. *Code of Federal Regulations, Title 40 Part 51.166*, 1999, U.S. Government Printing Office.
10. Seitz, J. S., 1997, Memo: *Agency Policy on the Use of Special Purpose Monitoring Data*, U.S.EPA.
11. Crocker Nuclear Laboratory, U.C. Davis, 1999, *Improve Particulate Monitoring Network Procedures for Site Selection*.
12. Calkins, D. L., 1998, *Global Partnerships: A Collaborative Effort to Improve Air Quality in Developing Countries*, 98-TA42.01, <http://www.epa.gov/ttn/amtic/files/ambient/gems/gpem10~1.pdf>.
13. U.S.EPA, 1998, *Air Quality Index Reporting, Proposed Rules*, 63 FR 6718.
14. Spare the Air, <http://sparetheair.com>.

This chapter will discuss the equipment used in ambient air monitoring first discussing the broad types of monitoring processes, then the operational principles of the equipment types, finally, operation of specific equipment. Additional information may be found in the EPA Redbook (Quality Assurance Handbook for Air Pollution Measurement Systems)¹ and the Air Resources Board air monitoring standard operating procedures manual (Air Monitoring Quality Assurance, Volume II: Standard Operating Procedures for Air Quality Monitoring).²

401 TYPES OF MONITORS

There are three principle types of pollutant monitoring processes: continuous monitors, time averaged samplers, and open path instruments. Gaseous pollutants are most commonly measured by continuous monitors while particulate matter is most commonly measured by time averaged samplers. In addition, meteorological instruments are commonly associated with ambient air monitoring stations.

401.1 CONTINUOUS MONITORS

Continuous monitors continuously sample, analyze, and report real time pollutant concentrations. These instruments generally have reference and measurement cells. The ambient air sample continuously flows through the measurement cell and absorbs light from a measurement light beam of a specific wavelength geared to analysis of the pollutant in question.

Included in this category are the semi-continuous methods that cycle through separate sample and analyze functions automatically. The sample/analysis cycle typically lasts no more than a few minutes. For example the TECO 55C hydrocarbon analyzer, used by the ARB for hydrocarbon measurement, conducts a chromatographic separation of methane and heavier hydrocarbons. The chromatographic cycle lasts for 300 ± 1 seconds.

401.2 SAMPLERS

Samplers use separate collection and analysis steps and do not provide real-time data. Most commonly, a sample of ambient air is collected and transported to a laboratory for analysis. Collection may be on a filter (primarily for particulate matter, analyzed for mass and possibly speciation), an adsorptive resin column (primarily for toxics), or in a canister (primarily for toxics). PM_{10} mass mea-

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surement, one of the most common pollutant measurements, is conducted in this manner. A preweighed filter is installed in the sampler and particulate matter filtered out of the ambient air for 24 hours. After sample collection, the filter is removed and returned to the laboratory for postweighing.

401.3 OPEN PATH INSTRUMENTS

Open path instruments (often referred to as remote sensing instruments) are generally continuous monitoring instruments; however, they do not contain a pollutant measurement chamber. The pollutant measurement is conducted through the atmosphere using a long path. These instruments may use an analysis path of up to several kilometers in length.

Open path instruments provide pollutant concentration data averaged across the entire pathlength, while traditional air monitoring techniques sample a single point in space. This can provide an advantage in well mixed atmospheres. The linear average can also provide an effective means of monitoring source specific emissions at the fenceline of the facility.

Open path spectroscopy is based on a monitor that directs a beam of ultraviolet, visible, or infrared radiation over an unobstructed optical path that contains the gases to be monitored. After passing one or more times through the atmosphere, the radiation is received by an optical sensor. A bistatic open path instrument contains a transmitter (source) unit and a separate receiver/

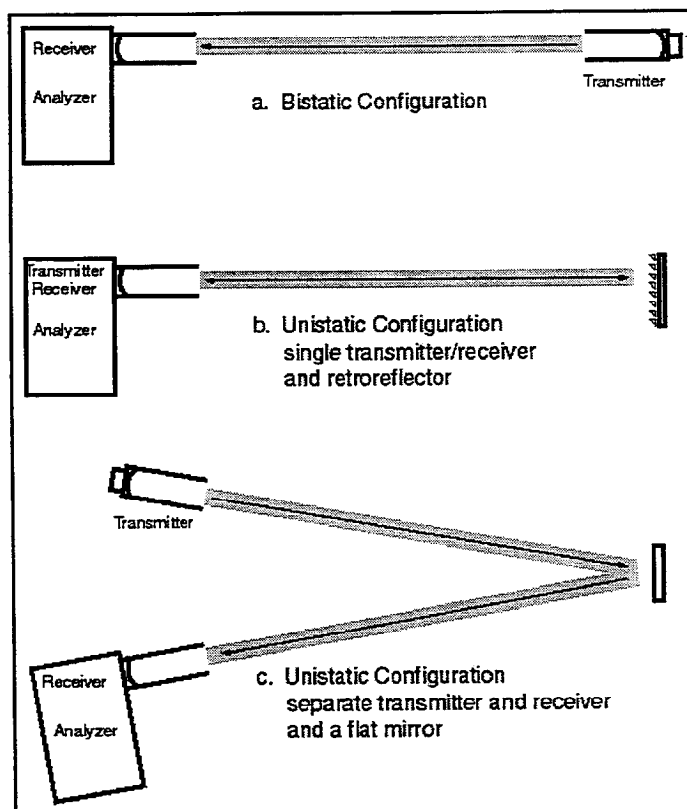


Figure 401.1 Configuration Options for Open Path Monitors³

analyzer unit (Figure 401.1a). A unistatic instrument has both the transmitter and receiver at a single location, either in a single unit (Figure 401.1b) or as separate units at the same location (Figure 401.1c). Unistatic configurations have the advantage of having all the active equipment at one place giving easier servicing and electrical power, etc. is only needed at one place. In addition, by folding the path back, the path length is doubled, enhancing the detection limit. The corner-cube retroreflector is also quite simple and forgiving to align.

The detector/analyzer may be a conventional, single pollutant system or, to measure multiple pollutants, a Fourier transform infrared (FTIR) system may be used. Use of an FTIR sensor allows interfering spectral features (H_2O , CO_2 , etc.) to be removed by using a scaled reference spectrum.

Path-integrated concentrations are measured as the total contaminant burden in the cylinder defined by the cross-section and length of the light beam (Figure 401.2). The concentration measured is in terms of ppm-m (ppm-meters -- the concentration averaged throughout the path length). By normalizing to a path length of one meter (dividing by the path length in meters) the ppm concentration is then calculated.

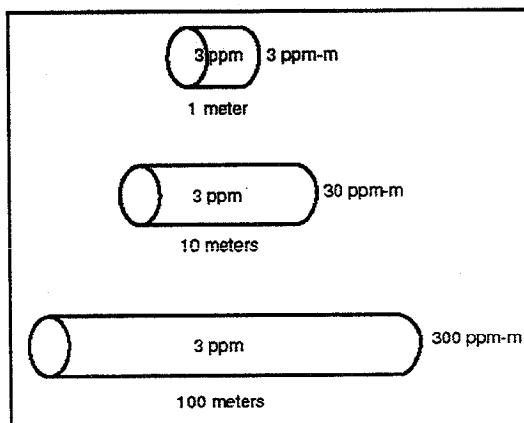


Figure 401.2 Path-Integrated Concentrations

An open path monitor for measuring visibility is generally referred to as a transmissometer. In this case the detector may be a photocell or a camera with the retroreflector replaced with a black and white segmented optical target whose contrast can be measured.

A differential optical absorption spectrometer (DOAS) is a long-path instrument that measures the concentrations of trace components in the atmosphere by their absorption of light in the UV and visible ranges. DOAS is especially useful in measuring pollutant molecules with pronounced vibrational structures such as NO_2 , HONO , and H_2CO . In the detector of a DOAS the radiation is spread into its spectrum by a grating. A rapidly scanning narrow slit allows a spectrum of approximately 500 digitized data points to be acquired. Similar spectra of the pure species are then used to deconvolute the complex ambient air spectra.⁴

402 ANALYTICAL TECHNIQUES

The basic ambient air monitoring techniques, whether using a continuous monitor or time averaging sampler, are straight forward; however, possible interferences must be taken into account when a monitor is designed. The specific circumstances in which the instrument produces valid data must also be defined. Therefore, the EPA had specific procedures to certify reference and equivalent monitoring equipment. Only certified equipment may be used for ambient air monitoring data for record. In the state of California, the ARB has a parallel process when applying monitoring methods in California. The certification process is discussed in sections 403.1 and 403.2 of this chapter.

There are many types and models of analyzers on the market, to make an appropriate choice of which to use it is important to understand the operating principles of the analyzers. The following subsections of this section will discuss the general principles of the monitoring instruments.

402.1 TECHNIQUES USING LIGHT

Most continuous monitors use interactions with light (absorption, fluorescence, or luminescence) with the pollutant molecules as their measurement principle. These monitors typically draw air through a measurement cell where the absorbance or emission of light is continuously measured.

Light can be characterized as waves of oscillating electric and magnetic fields. However, in interactions with matter, light behaves as if it were composed of discrete packets of energy, called photons.

The length of the oscillations of the electromagnetic waves of light is its wavelength (λ) (Figure 402.1). The units for wavelength are most commonly nanometers (nm, 10^{-9} m), although angstroms (\AA , 10^{-10} m)

and micrometers (μm , 10^{-6} m) are also used. The number of oscillation cycles occurring per second is termed the frequency (ν) of the light in hertz (cycles/second).

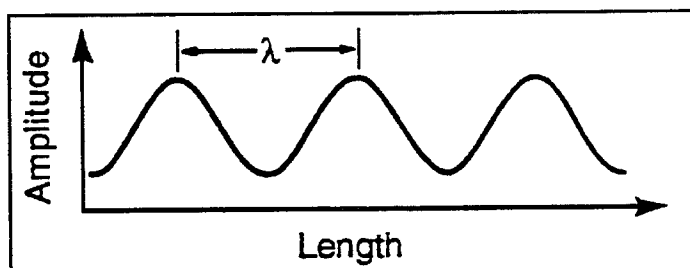


Figure 402.1 Wavelength of light

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The following describes the relationship between the wavelength and frequency
(c = speed of light; 3.0×10^8 m/s):

$$\nu = \frac{c}{\lambda}$$

The electromagnetic spectrum can be divided into several regions (Figure 402.2). Light with an intermediate wavelength (400 to 700 nm) is visible to the

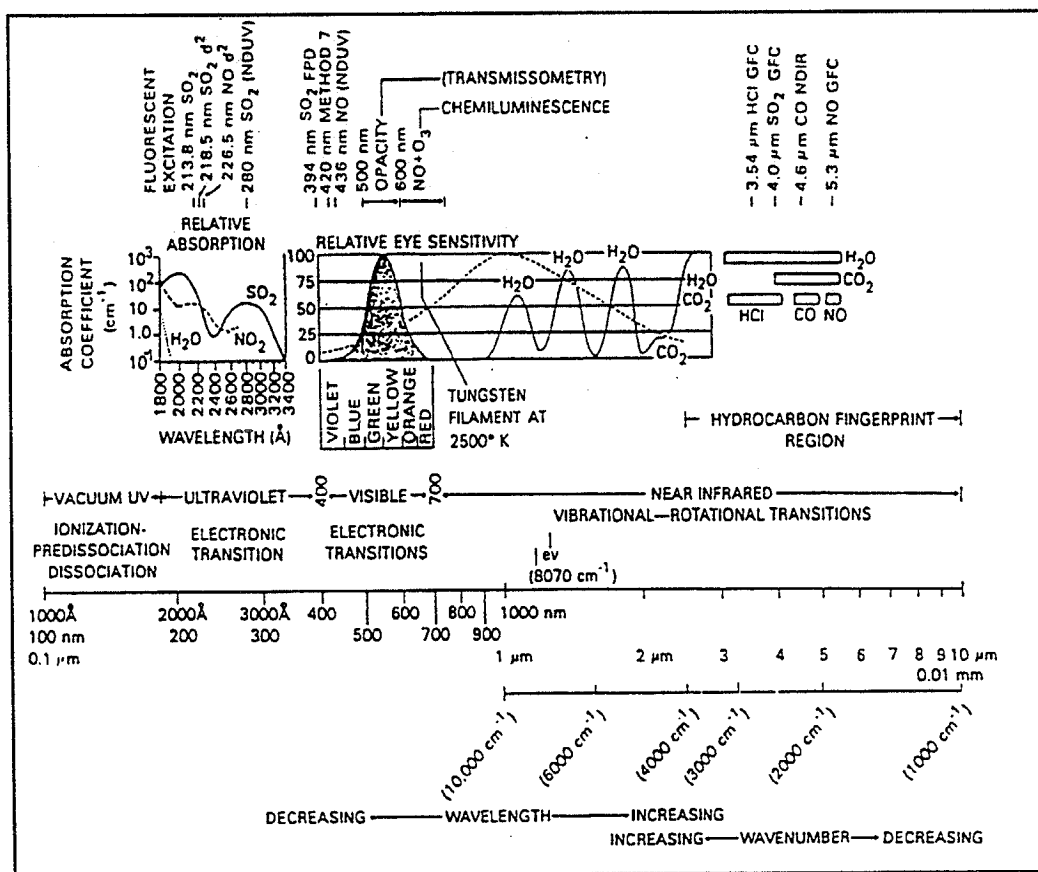


Figure 402.2 Spectrum of Light⁵

human eye; light with a shorter wavelength (less than 400 nm) is termed ultraviolet; and light of longer wavelength (greater than 700 nm) is termed infrared. In air pollution monitoring the wavelengths of light used range from approximately 200 nm in the infrared region of the spectrum to 6000 nm in the ultraviolet region.

The wavelength (or frequency) of light is dependent on the amount of energy carried by each photon. Light in the ultraviolet region has a shorter wavelength and higher energy while light in the infrared region has a longer wavelength and lower energy (E).

$$E = h\nu = \frac{hc}{\lambda}$$

Where h = Plank's constant, 6.63×10^{-27} erg-s

It should be noted that there is a significant difference between the energy of light and its intensity. The energy of light refers to the wavelength or frequency of each photon, i.e. how much energy is carried by the photon; the intensity of the light refers to the number of photons.

402.1.1 Absorption of Light by Gases

Molecules are made up of atoms and molecular electrons that are arranged in specific patterns which can undergo specific motions (vibrational or rotational).

If light of a given energy resonates with one of these allowed motions it will have a high probability of being absorbed by that molecule. Light that does not resonate will not be absorbed. The photon will be absorbed in total if it resonates, or passed in total if it doesn't. It will never be partially absorbed. Thus, light from a continuous spectrum, after passing through a gas, will have bands (or absorption lines) where the resonant photons have been absorbed (Figure 402.3). This process provides a means by which pollutant gases can be analyzed - by using a light consisting only of photons that will be absorbed. The concentration is directly related to the degree to which light is absorbed.

Beer-Lambert Law

When studying the absorption of light by gases, the Beer-Lambert law can be used to relate the amount of light absorbed to the concentration of the pollutant gas.

$$T = \frac{I}{I_0} = e^{-\alpha cl}$$

The Beer-Lambert law⁶ states that the ratio of the exit (I) and initial (I_0) light intensities, i.e. transmittance of light (T), through a pollutant gas is decreased

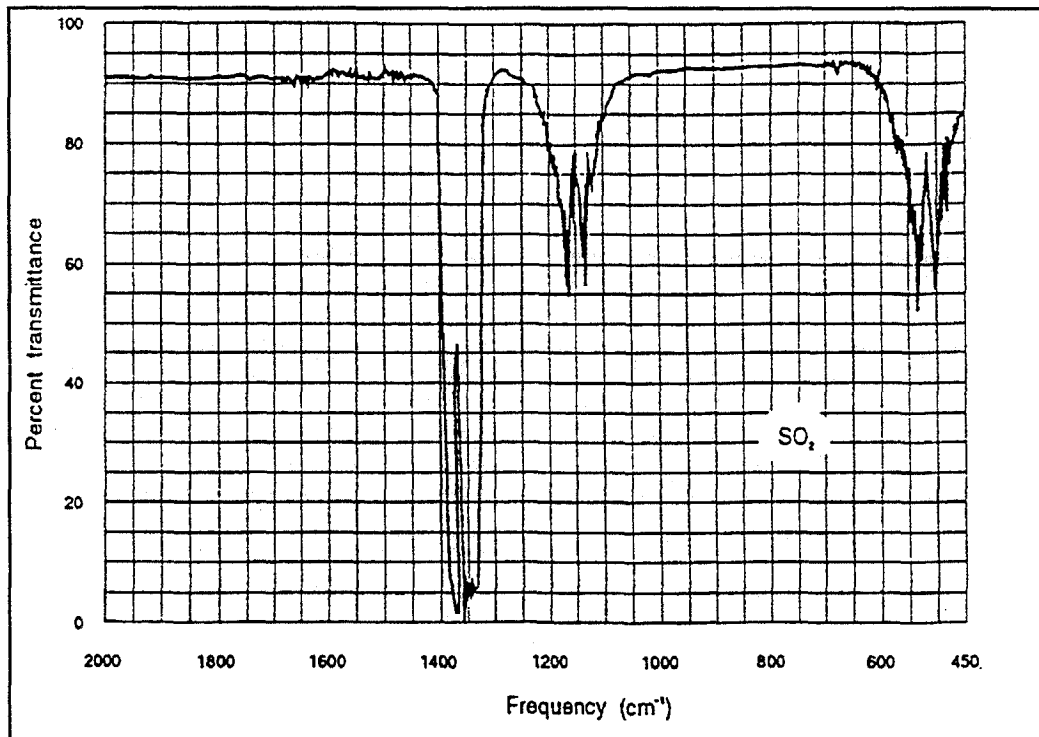


Figure 402.3 Infrared Transmission Spectrum of SO₂. An Absorption Spectrum Would be the Inverse of This Figure⁵

exponentially as the product of the molecular absorption coefficient (α), the concentration of the pollutant (c), and the pathlength through the analysis chamber (l). The absorption coefficient is dependent on the wavelength of light used for the analysis and the properties of the molecules detected.

This principle can be used to detect and monitor the ambient concentration of air pollutants. A light of the proper wavelength, selected to interact with the pollutant of interest and have no effects with any other gases in the air, can be passed through the sample cell. The intensity of the light will be attenuated by the pollutant. This attenuated measurement light beam then can be compared to the original intensity of the light and the concentration of the pollutant calculated from the ratio of the two light intensity measurements (I/I_0) by the Beer-Lambert law. The Beer-Lambert equation above can be rearranged to calculate the pollutant concentration:

$$c = \frac{-\ln\left(\frac{I}{I_0}\right)}{\alpha l}$$

Calibrations

A calibration of the instrument is important to compensate for the configuration and construction of the analyzer and the molecular absorption coefficient of the pollutant gas.

Usually an empirical calibration using several concentrations of the pollutant gas of interest is conducted rather than calculations based on theoretical values. A logarithmic plot (Figure 402.4) of the transmittance ($\ln(1/T)$) gives a straight line against which the measured gases can be compared and the concentration of pollutant gases calculated.

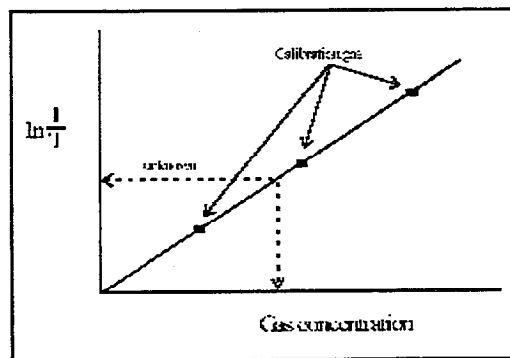


Figure 402.4 Calibration of an Analyzer

402.1.2 Absorption and Scattering of Light By Particles

In addition to interactions with gas molecules, light will interact with particulate matter.⁶ Particulate matter, including solid and liquid aerosols and droplets, will absorb and scatter light. The mechanisms of scattering are dependent on the size of the particle and the wavelength of light.

There are three basic types of scattering that occur. If the particle is much smaller than the wavelength of light, the particle-light interaction will be described by Rayleigh scattering. When the particle diameter is comparable to the wavelength of light, Mie scattering principles will apply. Thirdly, if the particulate is much larger than the wavelength of light, geometric optics explain the interaction. The atmosphere contains particles ranging in size from a few nanometers to 10 μm or greater, therefore, all three interaction types can occur.

Rayleigh Scattering

Particles smaller than 0.1 μm will scatter visible light by Rayleigh scattering principles. In Rayleigh scattering the instantaneous electromagnetic field of the incident light is uniform over the entire particle. This creates an oscillating dipole interaction with the electrons within the molecules of the particle by accelerating them. The oscillating dipole reradiates the electromagnetic radiation in all directions. The result of this phenomenon is that light is very effectively scattered out of the light beam.

Mie Scattering

When the diameter of the particle is on the order of the wavelength of light the molecular electrons no longer see a uniform electromagnetic field from the light. The electromagnetic field will vary in direction and intensity throughout the particle, causing the electrons to accelerate and scatter in different directions. The scattering light can constructively and destructively interfere giving a complex scattering pattern. A bright hazy appearance of the atmosphere is a result of forward Mie scattering.

Geometric Optics

For large particles, where the size of the particle is greater than 20 times the wavelength of the incident light, the interaction between light and the particle is described by geometrical optics. This interaction is described by individual rays of light that are reflected, refracted, diffracted, and absorbed by the particle.

Bouguer's Law

Particle scattering and absorption effects can be treated in a manner similar to the Beer-Lambert law for gases. Bouguer's law states that transmittance is decreased exponentially.

$$T = \frac{I}{I_0} = e^{-naQl}$$

Where n = number concentration of the particles

a = projected area of the particles

Q = particle extinction coefficient

l = pathlength

The particle extinction factor (Q) is dependent on the wavelength of light and particle size and expresses how the particle will absorb and scatter light (as discussed above).

402.1.3 Opacity and Transmittance

The transmission of light through air that contains particulate matter will be reduced by scattering and absorption processes. The scattering and absorption gives rise to the opacity, or opaqueness, of the air and reduced visibility. Clear

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air will have a transmittance of 100% (opacity of 0%). As particulate concentrations increase the transmittance will decrease (opacity will increase). Total obscuration would have a transmittance of 0% (opacity of 100%).

$$T(\%) = 100 - \text{Opacity}(\%)$$

Optical density (D) is related to opacity and transmittance as follows:

$$(\text{optical density}) = D = \log_{10} \frac{1}{1 - \text{opacity}} = \log_{10} \frac{1}{T} = \frac{naQl}{2.303}$$

In terms of particulate concentration (c) instead of the particulate number density (n), the expression can be written:

$$D = \frac{A_E cl}{2.303}$$

Where $A_E = \pi r^2 Q/m$, specific mass extinction coefficient
 r = radius of the particle
 m = particle mass

This expression is important in that it shows that the optical density is directly proportional to the particulate matter concentration and the pathlength. If the pathlength should be increased, the optical density will increase by the same factor (i.e. if the pathlength is doubled, the optical density will also double); also, if the concentration changes by some factor, the optical density will change by that same factor.

The optical density is important in visibility monitoring. It is related to the base ten logarithm of the inverse of the transmittance:

$$D = \log_{10}(1/T) = -\log_{10}(1 - Op)$$

or

$$Op = 1.0 - 10^{-D}$$

This will be important in discussions of visibility monitors elsewhere in this manual.

402.1.4 Analyzer Design

The analytical techniques used in monitoring systems encompass a wide range of chemical and physical measurement methods. These methods range from chemical reactions (e.g. chemiluminescent NO_x analyzers) and optical techniques (e.g. non-dispersive infrared (NDIR) absorption spectroscopy) to electroanalytical techniques (e.g. electrocatalytic oxygen analyzers).

Except for electroanalytical methods, the analyzers incorporate four primary components: 1) radiation sources, 2) spectral limiters, 3) optical components, and 4) detectors. Most electroanalytical methods use a heated catalyst bed to measure electrical flow induced by pollutant gas ionization or magnetic field effects, bypassing these listed components. The components in a specific monitor will differ depending on the analytical technique, but the following principles will generally apply.

Radiation Sources

The radiation source in a monitor provides the light with which to perform the analysis. In most instruments the radiation source is a light emitting device; however in luminescence methods the radiation source is the excited sample itself. The light used in continuous monitoring instrumentation ranges from 200 nm in the ultraviolet to 6000 nm in the infrared. The infrared and ultraviolet light are outside the visual range of human sight, therefore the light is invisible to the human eye. However, since molecules of gases can 'see' and interact with this invisible light it is a useful analytical tool.

Heated materials will emit light in the infrared region of the spectrum. Hence, most infrared sources are heated devices. Among these devices are Nernst globars (hollow zirconium and yttrium oxide rods), globars (silicon carbide rods), carbon rods, nichrome wire, and tungsten filament incandescent lamps. Other devices such as lasers and diode lasers are also used.

Visible light is usually generated by an incandescent lamp, filtered to exclude infrared and ultraviolet wavelengths. Visible sources are primarily used in visibility monitors where the peak spectral response is required to be in the visual range (500 to 600 nm). In addition, quartz halogen lamps and green LEDs are sometimes used as visible light sources.

Many of the ultraviolet sources use electronic stimulation and atomic transitions to generate fluorescence emissions in the ultraviolet range. The devices used in monitors include: hollow cathode gas discharge tubes, high-pressure hydrogen or deuterium discharge lamps, xenon arcs, and mercury discharge lamps.

Spectral Limiters

A spectral limiter restricts the wavelengths of light to only those of interest in the analysis process. If extraneous wavelengths are allowed in the monitor analyzing chamber, additional reactions or light absorptions could occur and interfere with a sensitive and clean signal from the instrument. The simplest spectral limiter is a filter that allows only a narrow band of wavelengths to pass through it. Interference filters consisting of thin metallic films on glass are commonly used in the infrared region.

Diffraction gratings are commonly used in the ultraviolet region of the spectrum. The diffraction grating consists of a flat glass or aluminum plate, or a concave surface that is ruled with very finely etched lines (approximately 750 lines per millimeter). Light from the grating will constructively or destructively interfere to separate light wavelengths.

Optical Components

Electro-optical continuous emission monitor system analyzers will inevitably contain a number of optical elements to direct and focus light. Lenses, slits, and diaphragms are used to focus light into the analysis chamber and onto the detector.

Half silvered mirrors are often used to split a light beam, part going to the measurement analysis system and part to the reference. This allows a single radiation source to serve both functions and reduces noise and variability in the analyzer.

Motor driven choppers are employed to produce an oscillating light source. An oscillating light produces an oscillating electrical signal from the detector which can more readily be selected and filtered by the instrument electronics. This reduces the noise in the signal and improves the sensitivity of the instrument. The back side of the chopper may have a mirrored surface to produce a simulated zero signal between each measurement pulse.

Detectors

The detector is a device to capture and translate the effect created by the pollutant gas on the analytical system. An electrical signal from the detector is further amplified, conditioned and stored by the electronics of the monitor instrumentation. The type of detector used depends on the type of monitor and the energy of light it is using.

Infrared light is fairly weak in the energy it carries, therefore, maximizing the sensitivity and discrimination of the detector is important. Infrared instruments typically use thermal detectors.⁷ Traditionally these detectors sense the pressure in a closed detector cell due to absorption and heating by the analytical light. Newer, solid-state devices such as mercury cadmium telluride, lead sulfide, or arsenic triselenide light sensitive cells are increasingly being used. The sensitivity of the solid-state devices is increased by chilling with a thermoelectric chiller.

In a pneumatic detector (Figure 402.5) a thin metal diaphragm separates two gas-tight chambers filled with a high concentration of the gas being measured. The gas molecules absorb the IR radiation causing the gas to heat up. Following gas law principles, the heated gas expands, causing a higher pressure in the detector cells. The measurement chamber of the detector will be heated less than the reference chamber, in direct proportion to the amount of IR radiation

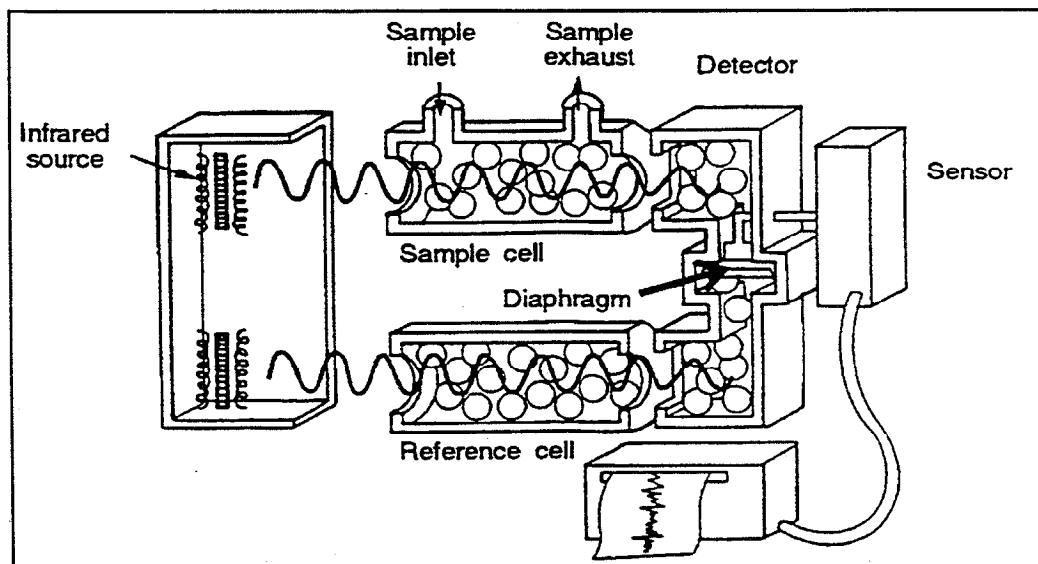


Figure 402.5 Pneumatic Detector⁵

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attenuated by the sample gas stream. The difference in pressure will cause the metal diaphragm to flex. In most designs a variable capacitance is measured between the flexing diaphragm and a charged, fixed metal plate. The distance between the plates is inversely proportional to the capacitance and directly proportional to the voltage.

Analyzers generally employ a rotating chopper wheel to produce a fluctuating light source. The light fluctuations result in oscillating pressures and, hence, oscillating voltage signals from the detector. The pneumatic detector operates somewhat like a microphone (and is sometimes referred to as a microphone detector).

The most significant problem with a pneumatic detector is that it is sensitive to vibration, which also flexes the diaphragm, producing a noisy signal. The device, therefore, must be isolated from vibrations.

A variation of the pneumatic detector which overcomes much of the vibration sensitivity uses a thin heated grid instead of a flexible metal diaphragm. The grid is cooled by the detector chamber gases moving between chambers to equalize the pressures. The grid functions in a manner like the heated wire flue gas velocity monitoring instruments.

Another variation of the pneumatic detector is the photoacoustic chamber detector (Figure 402.6). This detector uses a single chamber and measures the fluctuating chamber pressure with a condenser microphone. For the microphone of the photoacoustic chamber to work, the instrument must modulate the light beam at 20 Hz to 20 kHz. Again, these detectors are sensitive to vibration (especially in the frequency range picked up by the microphone). With a sensitive microphone a photoacoustic detector can measure pollutant concentrations to parts per billion levels.

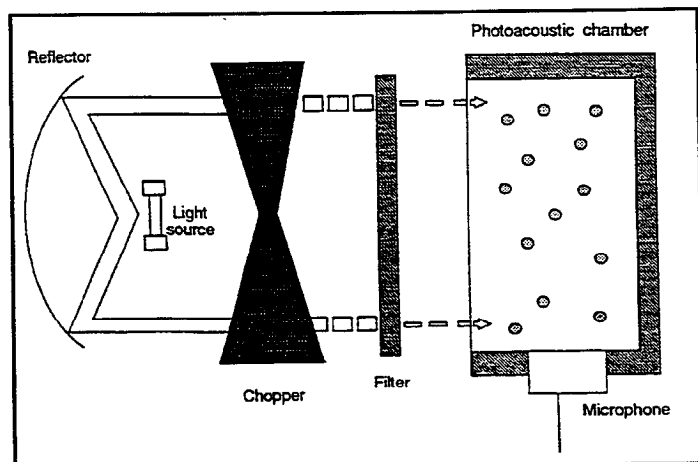


Figure 402.6 Photoacoustic Detector

For ultraviolet and visible monitors phototubes, photomultiplier tubes, and photovoltaic cell detectors are commonly used. Each of these devices produces an electrical voltage proportional to the amount of light that falls on the detector.

Solid-state detectors are also making inroads into monitoring instruments operating in the UV and visible light ranges.^{5,7,8} The prevalent solid-state device in use is the photodiode array detector (Figure 402.7). The photodiode array detector is a semiconductor array of 128 to over 4000 small diode elements. When light strikes the n-type semiconductor substrate an electron is freed which discharges a local diode element. The voltage needed to recharge the array is a measure of the light intensity.

By using a photodiode array detector with a diffraction grating, an entire spectrum can be obtained in a few seconds. In this way, these detectors are especially good for measuring multiple wavelengths or in instruments capable of monitoring multiple pollutant gases. For example, a photodiode array is frequently used in DOAS systems.

Another common solid state detector type is the photoconductive detector. This detector is a lead-selenide (Pb-Se)

device which operates through use of the photoelectric effect. That is, its conductivity is proportional to the light intensity hitting it. A photoconductive detector can be thought of as a photosensitive variable resistor that has high resistance at low light levels and low resistance at high light levels. These devices are temperature sensitive and must be cooled (usually with a Peltier chiller) to reduce background conductivity.

Electroanalytical instruments typically directly generate an electrical signal. That signal is then fed into the electronics and data storage functions of the instrument.

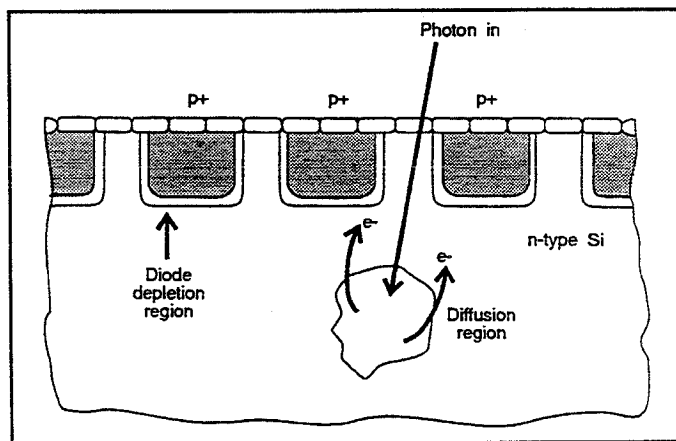


Figure 402.7 Photodiode Array Detector⁵

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Spectrometer Signal-to-Noise Ratio Performance

Evaluating the performance of a spectrometer includes a number of test such as measuring the signal-to-noise ratio (SNR), stability, spectral range, linearity, resolution, and wavelength accuracy. All these tests are important; however, the one that receives the most attention is the signal-to-noise ratio.

An instrument that delivers a high signal-to-noise ratio produces a higher quality spectrum in less time because less signal processing is required. This allows the spectrum to be sampled at a higher rate and greater sensitivity. In some instances, a high SNR is required simply to resolve the absorbance bands if the bands are extremely weak.

Spectral noise is generally measured in terms of peak-to-peak noise or root-mean-square (RMS) noise. Peak-to-peak noise is a measure of the difference between the maximum and minimum values in a given spectral region. The RMS noise is the square root of the average squared value of all points. Since RMS noise uses averaged values and not extreme values as does the peak-to-peak noise, RMS calculations are more reproducible. However, the result is about 4 to 5 times lower than peak-to-peak noise values and does not reflect the visual perception of noise or the case where spurious amplitude noise spikes are present. For example, in Figure 402.8 the peak-to-peak SNR is 0.006 while the RMS SNR is 0.002.

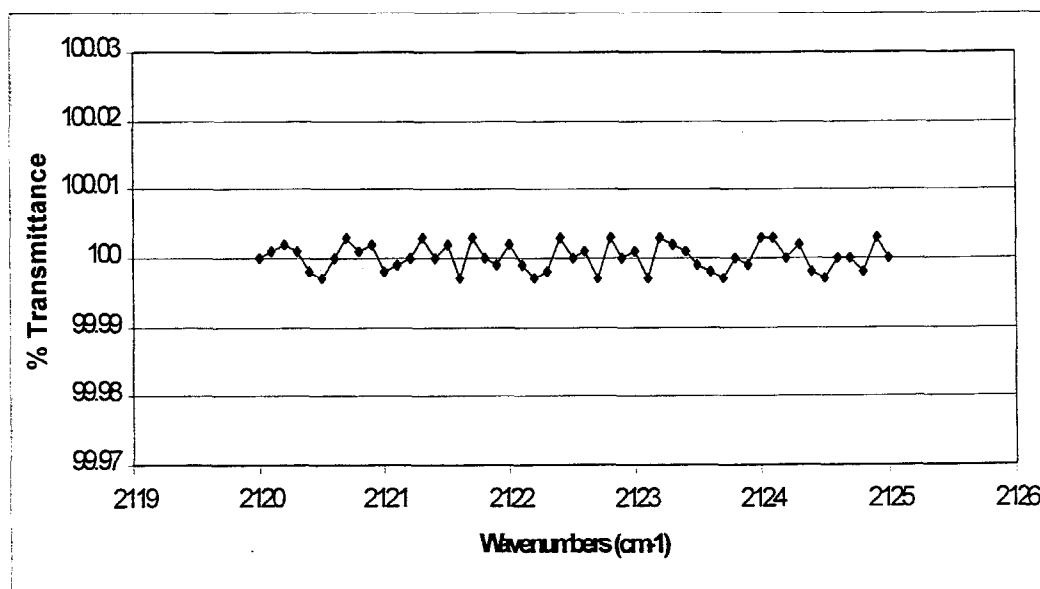


Figure 402.8 Signal-to-Noise Ratio Example

The SNR a spectrometer produces is proportional to the square root of the number of scans through the spectrum. The amount of time required to collect a given scan set can vary based on the scan velocity, duty cycle, and type of interferogram collected.

Environmental factors or system configuration will effect the outcome of the SNR test. The instrument must be fully purged and in equilibrium with its environment. Excessive vibration will also contribute to poor SNR. The SNR of a sealed and desiccated spectrometer will be about 10% lower than that of a purged system.⁹

402.1.5 Nondispersive Infrared Analyzers (NDIR)

Because of their simplicity, nondispersive infrared analyzers are frequently used. The term 'nondispersive' refers to the fact that a filter is used to select the wavelength of light for use in the analysis rather than a diffraction grating. A diffraction grating spreads, or disperses, the spectrum so a narrow band of light wavelengths can be selected. The filter allows the selected wavelength to pass through it; the remaining wavelengths are absorbed.

Table 402.1
Infrared Absorption Bands of Common Pollutant Gases

| Gas | Location of Absorption Bands (μm) |
|------------------|--|
| SO ₂ | 19.04, 8.70, 7.41, 4.00 |
| NO | 13.33, 9.52, 7.41, 6.15, 5.35, 3.45 |
| CO ₂ | 14.81, 4.26, 2.76, 2.68 |
| CO | 4.65 |
| HCl | 3.45 |
| H ₂ O | 6.25, 2.70 |

Infrared methods probably have been used for more pollutant species than any other method. Analyzers to measure SO₂, NO, CO, HCl, CO₂, and water vapor, as well as some hydrocarbons have been developed. Table 204.1 shows some of the absorption band of pollutants monitored by infrared methods. Note that some gases might have absorption bands that overlap with others. In specific, both SO₂ and NO have absorption bands at 7.41 μm , and CO₂ and H₂O have bands that are too close to differentiate (2.68 μm vs 2.70 μm). These overlap-

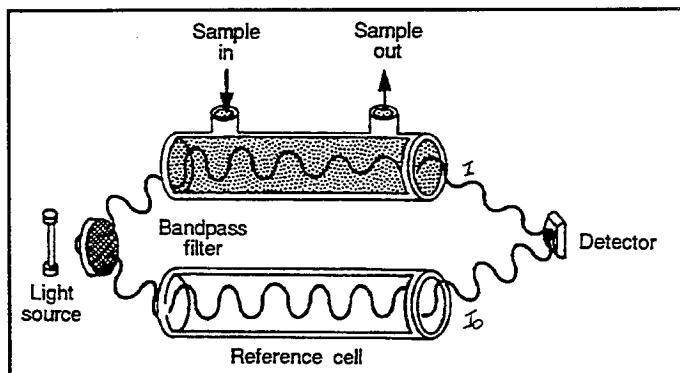


Figure 402.9 Simplified Diagram of an NDIR Analyzer⁵

ping regions present potential interferences; i.e. analysis at $7.41\ \mu\text{m}$ will measure the total of the SO_2 plus the NO .

In a typical NDIR instrument (Figure 402.9), infrared light is emitted from a source such as a glowbar. The light is transmitted through reference and

sample cells. The reference cell is filled with an inert gas (such as nitrogen) or clean, pollutant free air which passes the light unattenuated to give a reference value of the full initial light intensity (I_0).

The gas to be monitored is passed through the sample cell. The light passed through the sample cell is attenuated by absorption by the pollutant molecules (I). From the difference in light intensity the pollutant concentration can be calculated with the Beer-Lambert law (Page 400-6).

There are a number of IR detectors used. Most commonly, infrared monitors use pneumatic detectors or solid state photoconductive detectors.

402.1.6 Gas Filter Correlation Analyzers (GFC)

A variation of the NDIR technique is the gas filter correlation analyzer (GFC). Like the NDIR, the GFC is a Beer-Lambert law type device. However, in the GFC the absorption of light due to the pollutant gas is compared to a reference that is 100% absorbance rather than 0% absorbance. In the GFC technique¹⁰ (Figure 402.10) a relatively narrow-band light beam (but not restricted to the wavelengths absorbed by the pollutant gas) is intercepted by a rotating gas filter wheel. The filter wheel is partitioned into a reference sector and a measurement sector. There is usually also a dark sector for correction of variation of the electronics. The reference sector contains a 100% concentration of the pollutant gas which removes virtually all the light in the wavelengths in which the pollutant is active. The measurement sector contains a neutral gas (usually nitrogen).

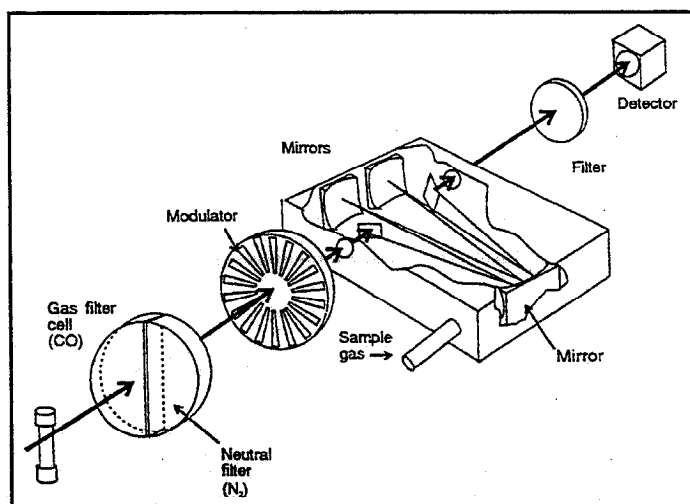


Figure 402.10 Gas Filter Correlation Analyzer Optical Chamber (Dasibi)⁹

When the light beam is intercepted by the reference sector of the gas filter wheel, virtually all the light in the wavelengths of light in which the pollutant is active is absorbed, rendering the remaining light insensitive to the pollutant (Figure 402.11). This gives a 100% absorbance reference signal. When the measurement sector rotates into the light

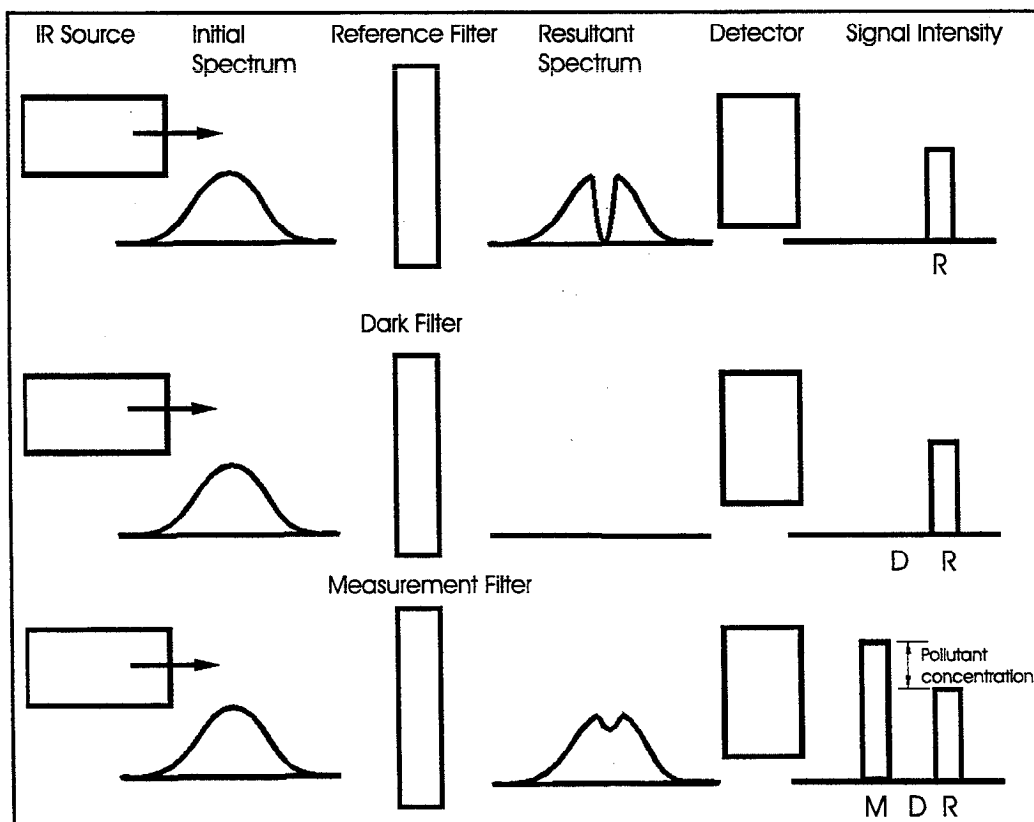


Figure 402.11 GFC Absorption Principles

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beam, only a portion of the light is absorbed by the pollutant to the degree dictated by the concentration of the pollutant gas in the sample stream. Gaseous species other than that of interest will attenuate both the reference and measurement signals equally and so will be canceled out.

A third portion of the gas filter wheel is blacked out to provide a dark sector. This dark sector provides a zero light reference to compensate for the dark current of the detector and electronics.

In most GFC analyzers the light enters a sample cell containing several mirrors. The light passes back and forth through the sample gas a number of times (typically 32 passes) which has the effect of extending the pathlength for absorption. For example, if the light makes 32 passes in a 25 cm optical table, the total pathlength will be 8 meters (800 cm). This gives the analyzer a far greater sensitivity while maintaining a compact device.

Gas filter correlation analyzers have been designed for monitoring SO_2 , NO , CO_2 , CO , ammonia (NH_3), water vapor, and HCl . The most common monitors for CO are GFCs.

There are several advantages of a GFC over a conventional NDIR analyzer. Because of the broader spectrum of light used, the method is not limited to a single absorption peak if there are several close together. The analyzer can measure over the broader spectrum, allowing the light from several absorption peaks to reach the detector, allowing more light to reach the detector. With the larger signal, simpler, more accurate, solid-state detectors can be used rather than chamber-type detectors. Also, because a ratio is obtained between the reference and measurement beams, biases in light intensity will cancel out, eliminating problems with infrared source instability and dirt accumulation on the optics.

The GFC can be used to monitor several pollutant gases at the same time. By using additional reference gas sectors (with 100% concentrations of the gases to be monitored) up to eight pollutant gases have been monitored simultaneously. Although they are not commonly available, such multicomponent analyzers have the potential to reduce monitoring system costs.

402.1.7 Fourier Transform Infrared (FTIR) Spectroscopy

The Fourier transform infrared (FTIR) process operates on the principle that when two beams of light are brought together they will constructively or destructively interfere depending on whether they are in phase or out of phase. These instruments are based on the two-beam interferometer invented by Michelson in 1891. The spectrum produced by an FTIR, even after the infrared spectrum is calculated from the interferogram, is the sum of all gases in the sample and looks very complicated due to the overlap of all the spectra. Inherent in this complexity is one of the advantages of the FTIR -- many gases can be monitored simultaneously.

An FTIR⁵ divides a beam of infrared radiation into two paths, then recombines them after a path difference is introduced by moving a mirror inward and outward in one light path. Interference develops between the beams, and the IR detector measures the variations in intensity of the beams as a function of the path difference. An FTIR uses IR sources that are virtually identical to the sources used in monochromatic infrared spectrophotometers (e.g. an NDIR instrument).

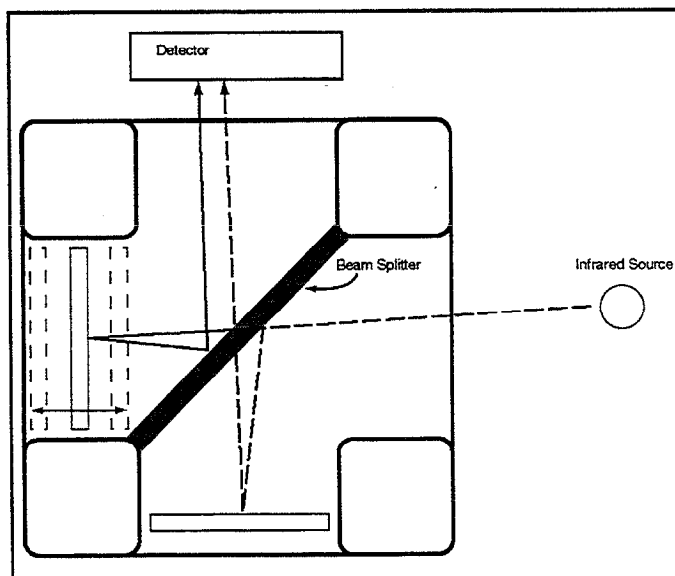


Figure 402.12 A Simple FTIR

A simple FTIR interferometer (Figure 402.12) consists of two mutually perpendicular mirrors, one of which moves to alter the radiation path length. The movable mirror must move at a constant velocity. A beam splitter between the fixed and movable mirror partially reflects the beam to the fixed mirror and transmits part of the beam to the movable mirror. The beams are reflected back to the beam splitter at which point they again are reflected and transmitted. Upon recombining they interfere to produce the intensity differences corre-

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sponding to the path dependent phase differences seen at the detector as a series of maxima and minima of intensities.

The interferogram (Figure 402.13) produced by an FTIR requires significant computer power to devolve into an analyzable infrared spectrum (Figure 402.14) via the Fourier Transform algorithm. A library of known spectra is then used to provide absorption coefficient data that is necessary to determine the individual gas concentrations. FTIRs are capable of measuring practically all airborne chemicals.

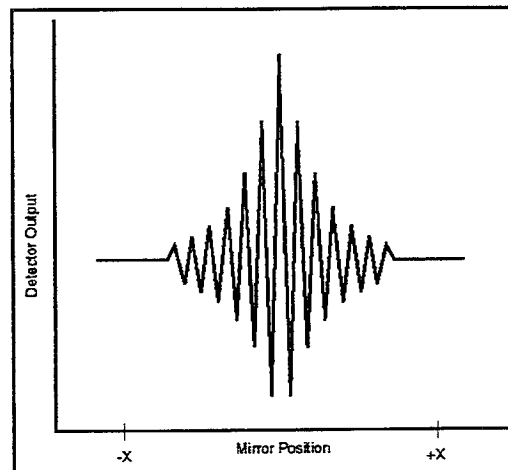


Figure 402.13 An FTIR Interferogram

With fast and powerful microcomputers the FTIR has been able to move from the laboratory into an instrument that can be deployed in ambient monitoring applications. The most common applications of FTIR in ambient air monitoring have been in long-path instruments.

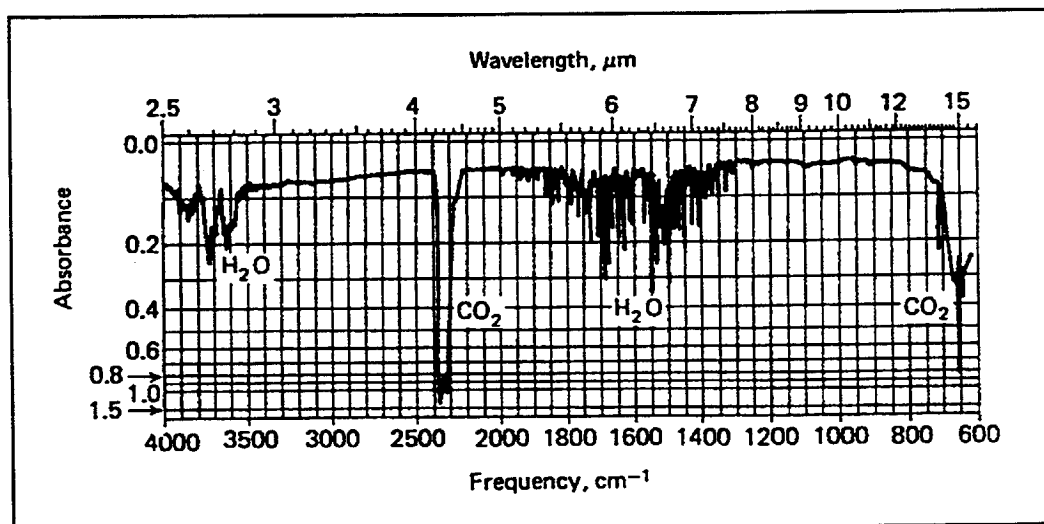


Figure 402.14 IR Spectrum of Air¹¹

402.1.8 Nondispersive Ultraviolet (NDUV) Analyzers

Nondispersive ultraviolet analyzers (NDUV) are very similar to NDIR analyzers; however, they use ultraviolet light rather than infrared. There are also a number of other differences due to the characteristics of ultraviolet light.¹²

The region of the ultraviolet spectrum in which practical analyzers operate extends from approximately 200 nm to 380 nm. This portion of the UV spectrum is considered the “near ultraviolet” being near the visible range. The region of shorter wavelengths (less than 200 nm) is considered to be “vacuum ultraviolet”. Since oxygen interferes with the analysis in the vacuum UV range, analysis must be conducted in a vacuum, design of monitoring instruments in this range is infeasible for that reason. Vacuum UV also can cause the gas molecules to dissociate. Wavelengths longer than 400 nm are in the visible range.

At the short wavelengths of UV radiation photons interact with the outer electrons of gas molecules, raising their energy levels. Other energies imparted to the molecules at longer wavelengths cause bond vibration and rotation interactions. All three effects superimpose so it becomes impossible to separate them. As a result, UV spectra tend to be spread over a range of wavelengths rather than having a sharp peak. On the other hand, the available UV radiation sources (typically mercury vapor lamps and hollow cathode lamps) offer line spectra rather than a continuous spectra such as that of an IR blackbody radiation

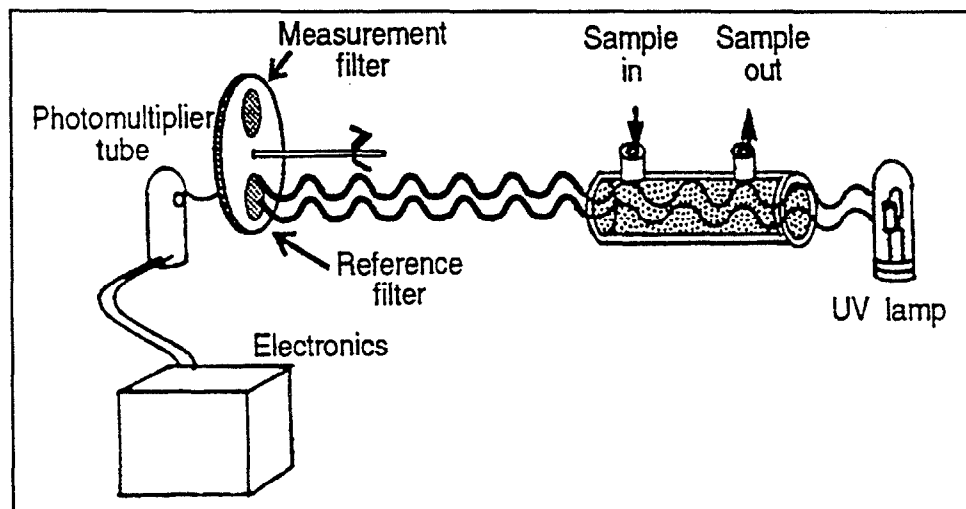


Figure 402.15 Operation of a Typical NDUV Analyzer⁵

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source. Additional spectral lines can be emitted by using phosphor compounds selected to emit light in the wavelength required for the analysis.

NDUV analyzers are commonly used in ambient monitoring to measure ozone. Sulfur dioxide and occasionally nitrogen oxide analyzers utilize NDUV in stack monitoring.

A typical differential absorption NDUV analyzer uses a single cell for both sample and reference measurements. Light from a UV source is alternately filtered to pass a wavelength in which the pollutant is active and a wavelength at which there is no absorption (Figure 402.15). For an SO₂ NDUV analyzer, the measurement wavelength is 285 nm and the reference wavelength is at 578 nm.

402.1.9 Fluorescence Analyzers

Fluorescence is a photoluminescent process in which light energy is absorbed at one wavelength and emitted at a different wavelength.¹² In this process the excited molecule will remain excited from 10⁻⁸ to 10⁻⁴ seconds. In this time some of the energy will be dissipated by rotational and vibrational motions, resulting in the emission light being lower energy (longer wavelength). Figure 402.16 illustrates this process.

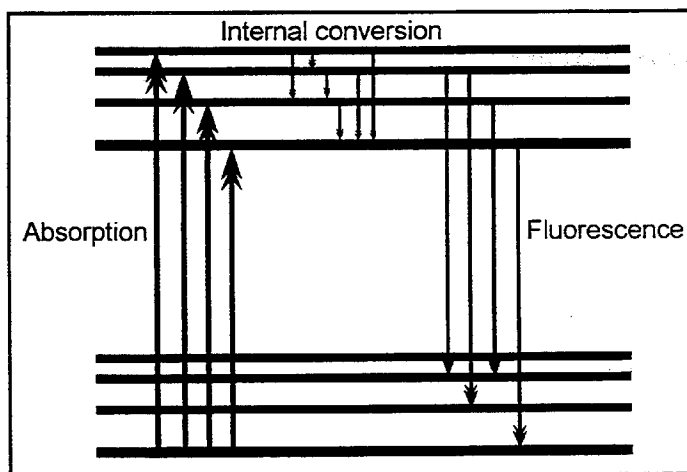
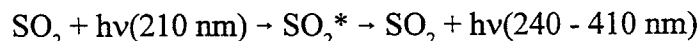


Figure 402.16 Energy Levels and Fluorescence

Since the energies of the light emissions will be lower than the excitation energy, the emission wavelength will be longer. The fluorescence process for SO₂ can be expressed as:



In a typical fluorescence analyzer (for example for SO_2 , Figure 402.17) the radiation is filtered to a narrow region. For SO_2 the region used is centered near 210 nm. There are three regions where SO_2 absorbs in the UV: 1) 340 - 390 nm, 2) 250 - 320 nm, 3) 190 - 230 nm. The first region exhibits only weak absorption and heavy quenching of the resulting fluorescent radiation. In the second region SO_2 absorbs strongly; however, the fluorescence is strongly quenched by oxygen and nitrogen in the air. The third region absorbs strongly and is only minimally quenched. Therefore, the third region is used for SO_2 fluorescence analyzers.

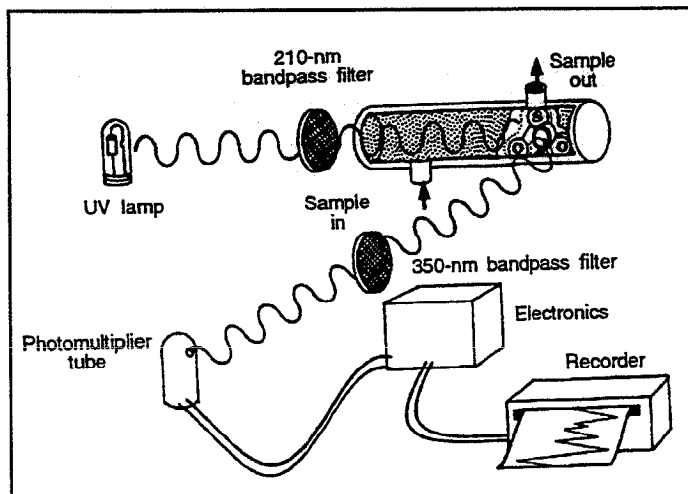


Figure 402.17 Typical Fluorescence Analyzer⁵

The fluorescent emission light is measured at right angles to the sample. The fluorescent emissions from SO_2 are in a range from 240 to 410 nm; a bandpass filter is used to select a portion of that light centered on 350 nm. At about 350 nm the spectrum is clear of most interferants.

One disadvantage of fluorescent measurements is fluorescent quenching. Water, CO_2 , O_2 , N_2 , hydrocarbons, and many other types of molecules can quench the fluorescence. In ambient monitoring these quenching molecules are rarely of high enough concentration to be a significant issue. However, this can be a significant problem in stack sampling where the concentrations of the quenching molecules can be quite high.

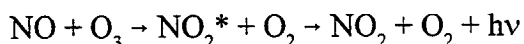
It is also important to calibrate the analyzer with standards made up in a gas mixture similar to the background mixture being analyzed; i.e. the calibration standards should be made up in air rather than in nitrogen. Spanning an instrument with a standard in nitrogen rather than air could give as much as 30% lower readings than the true values.

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402.1.10 Chemiluminescent Analyzers

Chemiluminescence analyzers operate on the principle that certain gas phase chemical reactions generate light.¹² NO_x monitoring is the most important use of chemiluminescent methods. Also, although not often used in the field, the reference method for ozone ambient monitoring is a chemiluminescent method (NDUV is the preferred ozone method).

The chemiluminescent NO_x method uses the reaction of ozone and NO to produce a visible to infrared light. This light is in the range from approximately 500 to 3000 nm; for analysis a filter is used to select light from 600 to 900 nm. The ozone required for this reaction is generated within the analyzer, no cylinders of expendable gases are required.



It's important to note that the gas phase reaction only occurs with NO. Nitrogen dioxide does not react with ozone. In order to monitor NO₂, the NO₂ is reduced to NO in a heated catalytic converter. The converter is generally made of stainless steel or molybdenum, which causes the NO₂ to decompose when heated. Molybdenum chambers are more frequently used since they catalyze the reaction at lower temperatures. A molybdenum chamber is operated at approximately 350°C. To calculate the concentration of NO₂, the concentration of NO is subtracted from the total oxides of nitrogen.

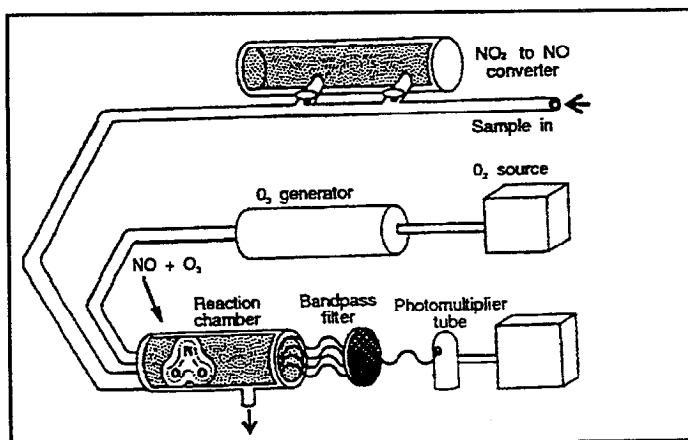


Figure 402.18 Chemiluminescent NO_x Analyzer⁵

In a chemiluminescent NO_x analyzer (Figure 402.18), ozone is generated by UV irradiation of atmospheric oxygen in a quartz tube. The ozone is provided in excess in the reaction chamber to ensure complete reaction and to minimize the

effects of quenching. The light generated by the reaction is filtered by a band-pass filter and the signal measured by a photomultiplier tube.

Because the photomultiplier tube signal is proportional to the number of NO molecules undergoing the reaction (rather than the NO concentration), the sample flow rate control and pressure regulation is of critical importance.

The chemiluminescent radiation can be quenched, as in fluorescence instruments, causing a low bias in the results. The quenching can be minimized by using a high flow rate of ozone and operation of the reaction chamber under reduced pressure.

The results can also be biased by oxides of nitrogen other than NO and NO₂. Ammonia (NH₃) will also bias the results since it will oxidize to NO in the converter. Using a molybdenum converter reduces this bias because of its lower operating temperature.

402.2 GAS CHROMATOGRAPHY

Gas chromatography is a physical method for separating components in a mixture of gases. It is commonly used to monitor hydrocarbon concentrations.¹³ Since hydrocarbon regulations generally apply only to non-methane hydrocarbons, a method to separate the methane from the non-methane hydrocarbons is required. Gas chromatography (GC) fits that need. The basis of the method (Figure 402.19) lies in the separation column, which is usually a small diameter tubing packed with a stationary bed with a large surface area. The mobile phase

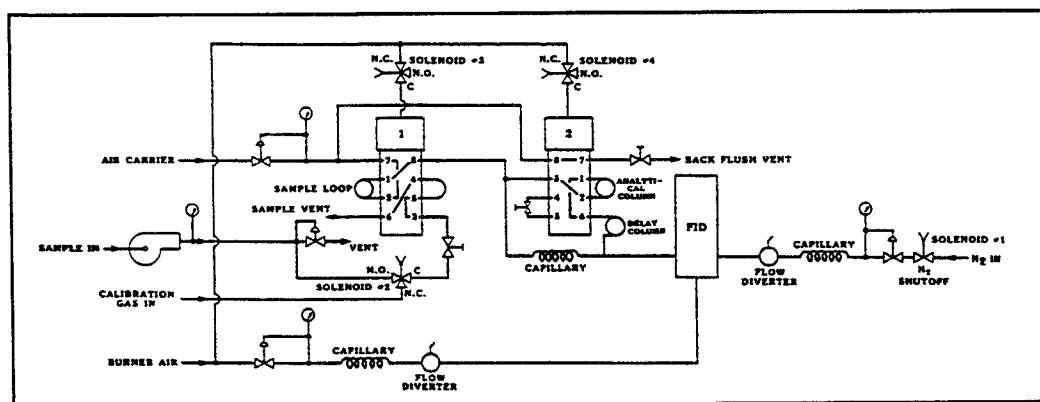


Figure 402.19 Gas Chromatograph Hydrocarbon Analyzer (Bendix 8202A, in Sample Inject Mode)

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(consisting of the sample and a carrier gas) percolates through the stationary phase.

The basic process responsible for the separation lies in differential retention of the sample on the stationary phase. The retention may be based on adsorption, solubility, chemical bonding, polarity, or molecular filtration properties. However, in all cases, the retention is reversible. The sample molecules are reversibly retained on the stationary phase in proportion to the sample, stationary phase, and carrier gas

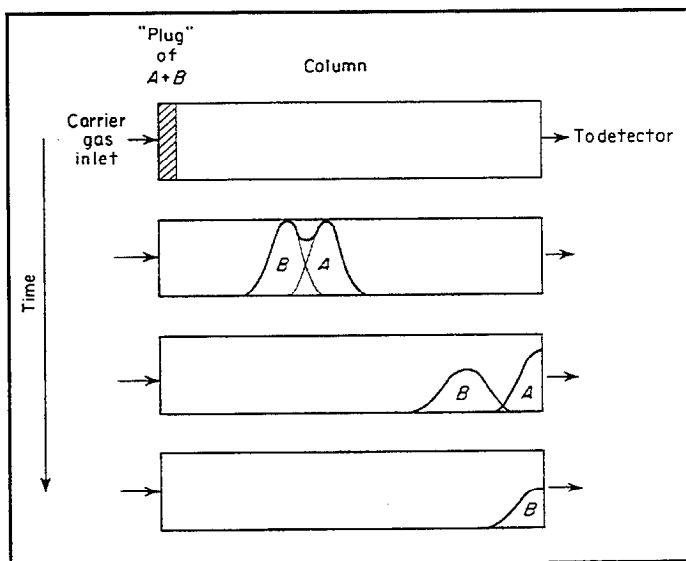


Figure 402.20 Gas Chromatographic Elution¹³

properties. At the outlet of the column the compounds in the sample will have been separated based on their retention properties on the column in use, with some compounds being retained longer than others (Figure 402.20).

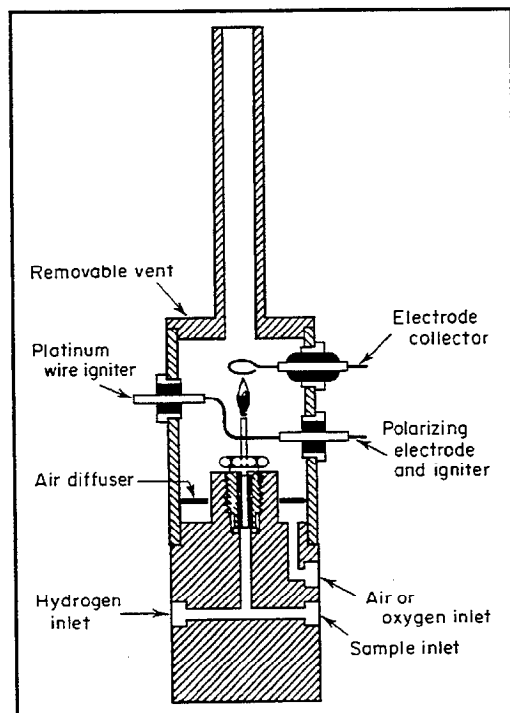


Figure 402.21 Flame Ionization Detector¹³

By using different column packing materials, temperatures, or column dimensions the rate at which a sample travels through the column (elution rate) can be controlled. If desired, a GC can be used to separate all components of the sample to obtain a complete analysis of the presence and concentration of every hydrocarbon in the sample. However, for most ambient monitoring purposes separation of methane from non-methane hydrocarbons is the extent of separation needed.

The temperature of the column is important to sample compound separation. The higher the temperature the faster the sample will elute through the column. At high temperatures, however, the separation of hydrocarbon compounds will decline. The temperature at which the GC is operated must be high enough for rapid sample elution, but low enough to separate the methane from non-methane hydrocarbons.

Upon emerging from the column, the separated sample enters the detector. A flame ionization detector (FID) is commonly used in ambient air monitoring (Figure 402.21). As the sample enters the detector, hydrogen fuel is mixed with the sample and air is mixed axially around the jet. The hydrogen flame burns at the tip of the burner and ionizes the molecules in the sample. The burner serves as a cathode and a loop of wire above the flame serves as the anode. An electrical current between the burner and the wire anode is formed in the flame. The typical current is about 10^{-12} amps.

The FID is essentially a carbon counter. A large, complex hydrocarbon will generate a larger signal than a small hydrocarbon with few carbon atoms. If the specific compound is known, the output of the FID can be calibrated to the number of carbons in that compound. Otherwise, the output is generally stated relative to a reference compound; i.e. stated as "measured as hexane".

The FID is quite sensitive to hydrocarbon compounds and insensitive to water, inorganic compounds, and background gases in the air and most stacks.

402.3 ELECTROANALYTICAL AND MAGNETIC METHODS

Another class of monitoring instruments is based on electrical and magnetic principles to determine gas concentrations. The magnetic methods measure the magnetic behavior of the gas in response to a magnetic field and can be divided into thermomagnetic, magnetodynamic, and magnetopneumatic instruments. The electroanalytical methods measure an electrical current in response to the pollutants in the analyzer.

The most common use of these analyzers is to measure oxygen concentrations in emission sources. These methods are rarely used for ambient monitoring. Information about these methods of analysis can be found in the *Continuous Emission Monitors* CAP Manual.

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402.4 PHYSICAL MONITORING/SAMPLING TECHNIQUES

This category of ambient air monitoring techniques uses physical and chemical properties of the pollutant to collect and analyze the pollutant concentrations. Many of these techniques rely on separate collection and analysis steps (i.e. sampling techniques rather than continuous monitoring techniques).

402.4.1 Particulate Samplers

Although some new automated monitor-type instruments are becoming available, for the most part particulate matter is measured by time-averaging samplers rather than continuous monitors. Most particulate measurements are made on filters that are manually loaded into, and unloaded from, the sampler and shipped to a laboratory for analysis.

The most commonly measured property of particulate matter is mass. Whereas the number of particles is most related to the health effects of particulate matter; the number of particles is difficult to measure. The total mass is correlated to the number concentration of particles within a size range.

The total number of particles is also related to haze, or visible attenuation and scattering in the atmosphere. The particles that form haze are very small size and long lasting in the atmosphere. The diameter of haze particles is approximately equal to the wavelength of light (0.4 to 0.7 μm).⁶ Haze is important in scenic areas where the visibility is the *raison d'être* for many parks. It is also important to the public since people don't think the air is polluted until they see haze. Section 202.1.2 of this manual discusses the properties of particulate matter in additional detail, for more information please turn to that section.

Particulate matter sampling consists of three phases: particle size selection, particle capture, and analysis. Particle size selection is important in defining the sample. Sizing is generally accomplished by inertial separation which uses the velocity of the airstream and abrupt changes in direction to remove larger particles. By careful selection of the velocity and spacing in the inertial separator, specific size selection can be assured. The design and calibration of the sampler is important in maintaining the required sharp size cutpoint.

Particles meeting the size requirement are captured on filters. Except for special purposes, glass fiber filters are used.

Mass analysis consists of pre- and post-weighing of the filters at a laboratory. If desired, additional analysis may be conducted on the particulate matter collected on the filters. The filters may be chemically extracted and analyzed (i.e. lead analysis by atomic absorption or sulfate and nitrate analysis by ion chromatography) or a segment of the filter excised and directly analyzed (i.e. XRF for metals).

402.4.2 Continuous Particulate Monitors

Although the NAAQS for particulate matter requires 24 hour daily average samples, continuous particulate monitors have been shown to provide important additional information. Daily averages for comparison to the NAAQS can be constructed by averaging the shorter time increments. Continuous particulate matter monitors can provide automated, continuous, near real-time online data that may be combined with meteorological data to help analyze temporal particulate matter observations. These observations show how particulate concentrations may be influenced by wind direction, wind speed, diurnal temperature patterns, surface layer inversions, present weather, and local topography.¹⁴ These data may also be invaluable for instituting and evaluating regulatory programs, an aid in identifying and analyzing pollutant episodes, and a compliance and enforcement tool.

Beta Attenuation Monitors (BAM)

Beta attenuation particulate monitors measure the concentration of particulate matter by measuring the attenuation of beta radiation by particulate matter collected on a filter tape. A drawback of this method is that it requires a radioactive source to produce the beta radiation (although typically quite low level, i.e. ~100 mCi of carbon 14). In addition, BAM depends on the calibration of mass to beta radiation attenuation, which depends on inherent properties of the particles rather than the mass.

Light Scattering Devices

Light scattering devices may either collect particulate matter on a filter or conduct their measurements directly on the particulate in the air. These devices measure light scatter and absorption and correlate that measurement with particulate concentration. Since they measure the effect of particle optical properties rather than the mass, significant inaccuracies may exist; especially with particles of unknown optical properties.

Tapered Element Oscillating Microbalance (TEOM®)

The TEOM® system (TEOM is a registered trademark of Rupprecht & Patashnick Co., Inc.) for ambient air monitoring uses a filter cartridge on a hollow tapered tube (Figure 402.22). Particulate matter is collected on the filter.

As the mass of particulate matter on the filter increases the frequency of oscillation changes. A comparative illustration could be the vibration (sound) of different size and mass tuning forks. Thus this instrument directly determines the mass of particulate matter in real time. By combining the mass with the known flow rate, the ambient particulate concentration can be determined.¹⁵

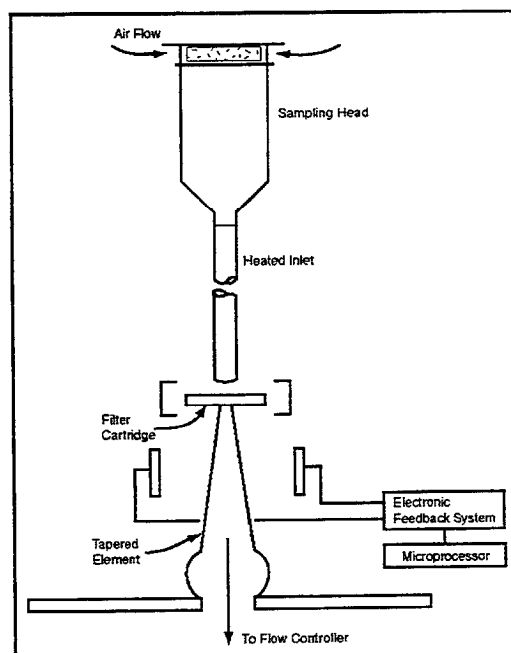
The tapered tube (with filter) is maintained in oscillation in a clamped-free mode. The frequency of oscillation is dependent on the physical properties of the tapered tube and the mass on its free end. The feedback electronics maintain the tapered tube in oscillation. A precision frequency counter measures the oscillation frequency and provides an output to the microprocessor.

The oscillating tapered tube and filter can be considered a simple harmonic oscillator. As such, it can be readily described mathematically through equations relating the frequency of oscillation, restoring force constant, and the mass:

$$\omega = 2\pi f = (k/m)^{0.5}$$

where:

- f = the natural frequency
- k = the restoring force constant
- m = the oscillating mass



**Figure 402.22 Diagram of
TEOM® Ambient Particulate
Monitor**

or:

$$f^2 = K_o/m$$

where:

$$K_o = K/4\pi^2$$

In the case of the microbalance, m is the total mass of the filter (m_f), plus the effective oscillating mass of the tapered element (m_o), plus the filter loading (δm), where:

$$m = m_f + m_o + \delta m$$

Calibration of the microbalance is accomplished by placing a predetermined mass on the surface of the filter. The change in oscillating frequency with and without the calibration mass (f_f and f_i) can be observed and the constant K_o calculated. From which a mass/frequency relationship can be determined:

$$\delta m = K_o(1/f_f^2 - 1/f_i^2)$$

As can be seen, the collected particulate mass is independent of the mass of the filter (m_f) and the effective mass of the oscillating tapered element (m_o). In successive mass measurement, the total mass of the system is implicitly contained in the starting frequency (f_i). The final frequency (f_f) is different from f_i only as a result of the mass uptake added (δm) during the measurement period. Although the nature of the relationship between the frequency and the mass uptake is not linear, software used in the microprocessor can as easily calculate a nonlinear relationship as a linear one.

402.4.3 Toxics

Toxic pollutants may be in the form of gases, vapors, or particulates. Therefore, how the toxic pollutant is collected depends on its form. Toxic pollutants are also usually collected and returned to a laboratory for analysis rather than measured by continuous monitor since they are generally in very low concentrations in the air. Laboratory analysis can use concentrating methods or analytical instruments that are too delicate or expensive to locate in a field environment.

Toxic particulate pollutants are generally collected on filters. The filters are then extracted and analyzed in the laboratory. The ARB generally analyzes for particulate heavy metals on filters by XRF or by extraction and analysis by IC. The filters may be run on hi-vol, dichotomous, or Xontech samplers.

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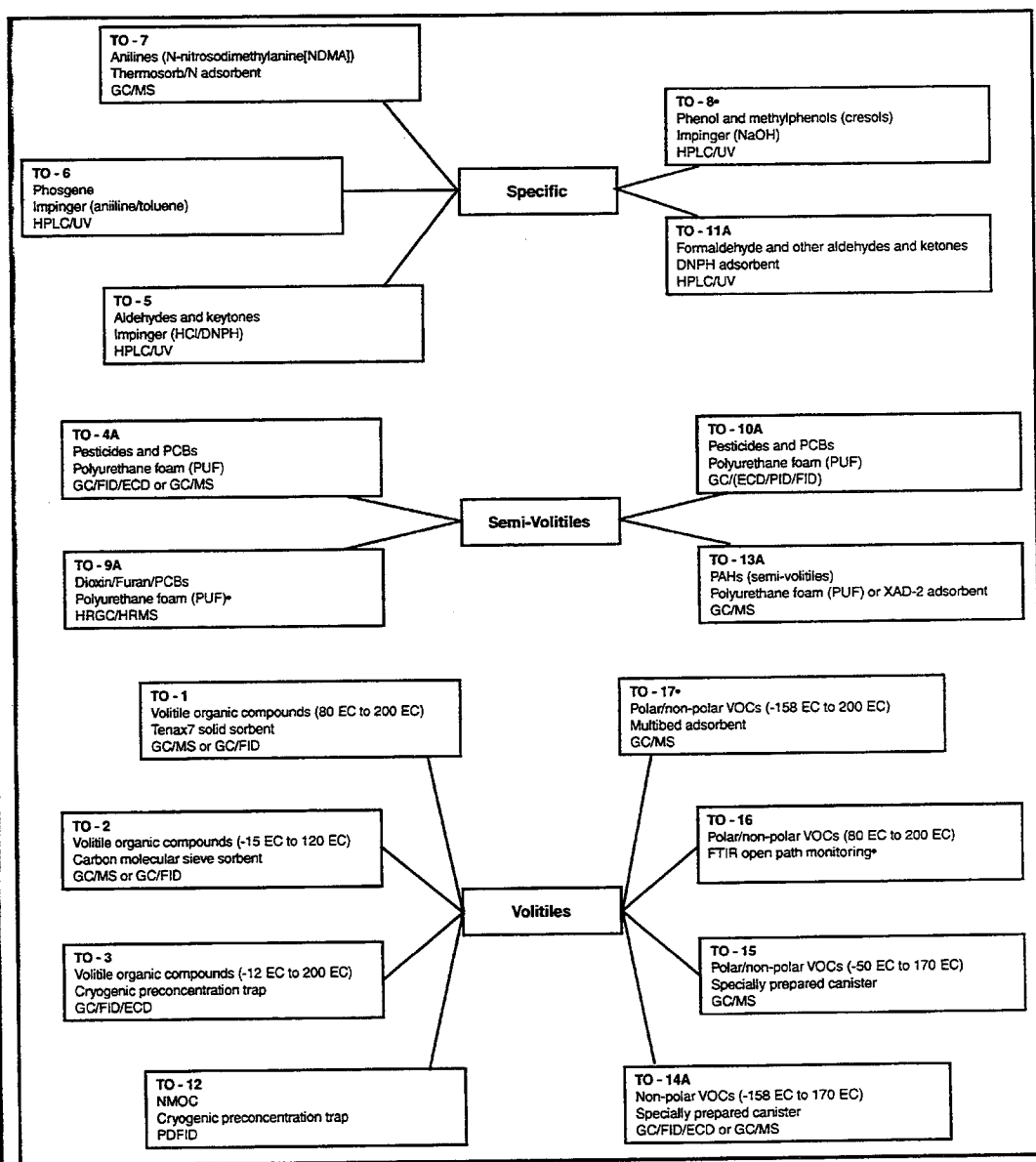


Figure 402.23 U.S.EPA Methods for Determination of Toxic Organic Compounds in Ambient Air¹⁶

Gaseous and vapor toxic pollutants may be collected in a number of ways (Figure 402.23). The most common means of collection are in adsorbant tubes and in evacuated canisters. The method used to collect and analyze the toxic air pollutants depends on the properties of the pollutant; as can be seen in Figure 402.23 which illustrates the U.S.EPA toxic methods, the pollutant measured, the method of collection, and the method of analysis. The California Air Resources Board uses evacuated SUMMA stainless steel canisters to collect samples for aromatic, halogenated compounds, butadiene, benzene, and MTBE analysis. After 24 hours of sampling, the canisters are pressurized to approximately 12 psig. The ARB also uses Sep-Pak silica cartridges coated with acidified DNPH for aldehyde analysis and PM_{10} filters for PAH analysis.

402.4.4 Acid Deposition

Acid deposition can be divided into three principle parts: wet, dry, and acid vapor deposition, each of which are collected in a different manner.

Wet Acid Deposition

Wet acid deposition sampling entails collecting rainfall and analyzing it for pH and several chemical constituents related to acidity (e.g. nitrate, sulfate, chloride, etc.). The concentrations of the acidity components are generally quite low and the rainfall water poorly buffered; therefore, care must be exercised in the collection to prevent contamination and alteration of the sample. When collecting the samples, the collection buckets must be very clean and the sample retrieved and sent to the laboratory immediately after the rainfall event. Studies¹⁸ have shown significant (sometimes nearly total) loss of metals within hours of collection if the sample is left in the collection bucket.

Dry Acid Deposition

Dry acid deposition principally consists of the deposition of acidic particulate matter. Acidic gases and vapors can also be grouped with dry acid deposition. Of greatest concern for particulate acid deposition are nitrate and sulfate containing particles. In the eastern United States sulfate containing particulate matter is the primary acid species. However, in California (especially southern California) nitric acid predominates.

Nitric acid particulate matter can be especially difficult to collect since it is highly volatile. Nitric acid particulate matter will vaporize under vacuum or

high temperature. For this reason, nitric acid particulate matter is collected on nylon filters which chemically adsorb nitrate. In addition, since nitrate also exists as a vapor in the atmosphere, the vapor (which would also be adsorbed by the nylon filter) must be removed before particulate collection. The common means of vapor removal is via a denuder (see Section 402.4.5). To determine the total nitrate in the atmosphere two samples are used: one denuded and the other not. The quantity of nitric acid vapor is determined as the difference between the two measurements.

A number of acidic gases and vapors can be collected and analyzed. As stated above, nitric acid vapors can be collected on nylon filters. By impregnating cellulose fiber filters with adsorbant chemicals, many other species can be collected; i.e.: potassium carbonate for SO_2 , triethanolamine (TEA) for NO_2 , and citric acid for ammonia. It is important to analyze ammonia and ammonium in addition to the acidic compounds since $\text{NH}_3/\text{NH}_4^+$ are important neutralizing compounds and play a role in the acidic balance.

402.4.5 Denuders

Denuders are very useful in separating gases from particulate matter. This is important in preventing gas to particulate conversion artifacts on filters. Denuders also can be coated with an adsorbant chemical and used as a measurement tool for extracting and analyzing the adsorbant.

A denuder is based on diffusion properties.⁶ Gases traveling through the denuder have a higher diffusion coefficient than particles and, therefore, are more likely to diffuse to the wall of the denuder. If the denuder is made of an adsorptive material (or coated with an adsorptive material) the gases will be removed. Particles, being less diffusive, will traverse the denuder uncollected. Proper sizing and flow through a denuder is readily calculated; however, the proper flow rate must be maintained to prevent penetration of gases or collection of particulate matter.

402.4.6 Impingers

Impingers consist of a solution in which the pollutant of interest will dissolve or absorb. Air is drawn through the solution (dispersed in small bubbles to increase dissolution surface area) for the sampling period. After the sample is collected, the impinger is sent to a laboratory for analysis.

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Ambient Air Monitoring

Impingers are rarely used today since other methods of analysis, particularly the continuous monitors, offer much better analysis, immediate online results, and avoid many of the problems in dealing with transporting and using solutions in a field situation.

402.5 LABORATORY ANALYSIS

Many ambient air monitoring methods (particularly the manual sampling methods) depend on laboratory analyses to produce the pollutant measurement data. In order to perform sampling and analysis operations consistently, standard operating procedures (SOPs) must be written and followed. The SOPs detail the methods for operation, analysis, reporting, and other actions to be taken in association with the ambient monitoring.

Many of the procedures are delineated by the EPA reference or equivalent method being used. However, it is the responsibility of the monitoring/laboratory organization to develop a set of SOPs that pertain to the specific circumstances encountered.

For ambient air samples to provide useful information, the analyses must meet four basic requirements:

- Equipment must be frequently and properly calibrated and maintained;
- Personnel must be qualified to make the analyses;
- Analytical procedures must be in accordance with accepted practice; and
- Complete and accurate records must be kept.

Laboratory activities associated with ambient monitoring are primarily focused on the analysis of lead, particulate matter, hydrocarbon, and toxic samples. In addition, many laboratories also prepare reference and audit/quality assurance materials, test and certify instruments, and perform other activities necessary to collect and report measurement data.

403 AIR MONITORING EQUIPMENT OPERATION

In the previous section the general properties and principles of air monitoring were discussed. In this section general characteristics of common monitoring

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instruments and their operation will be discussed. For specific procedures for operating an instrument, an operator should refer to the equipment manual and agency SOPs.

403.1 EPA REFERENCE AND EQUIVALENT METHODS

Reference or equivalent methods are usually required for SLAMS or NAMS monitoring.¹⁷ In addition to SLAMS and NAMS monitoring, most other monitoring programs also require that reference or equivalent methods be used. Requiring the use of reference or equivalent methods helps assure the reliability and quality of air quality measurements. Specifically, reference and equivalent methods help assure: ease of specification, a guarantee of minimum performance, better instruction manuals, flexibility of application, comparability with other data, and increased credibility of measurements. The use of reference or equivalent methods does not, alone, assure the quality of the data; a quality assurance program is still a critical part of a successful monitoring program.

Appendix B of this manual contains the list of EPA reference and equivalent methods, the most up-to-date list can be found in the EPA AMTIC web pages (<http://www.epa.gov/ttn/amtic/>). New methods, as they are added to the list of designated methods, are published in the *Federal Register* at the time of their designation.

The definitions and requirements for reference and equivalent methods are given in 40 CFR 53.¹⁹ Reference methods are those monitoring methods that are designated as reference methods in an appendix of 40 CFR 50 (Appendix A - sulfur dioxide, Appendix B - suspended particulate matter, Appendix E - hydrocarbons, Appendix G - lead, and Appendix J - PM₁₀) or have been certified as a reference method by testing in accordance with provisions of 40 CFR 53. Similarly, an equivalent method is one that has passed the certifications tests of 40 CFR 53. In practice, there is no difference between application of a reference or an equivalent method.

Appendices A and G specify unique manual reference methods for SO₂ and lead. For these pollutants any method other than the manual reference method in the respective appendix of 40 CFR 50 is an equivalent method.

Reference methods for PM₁₀ must conform to 40 CFR 50 Appendix J and 40 CFR 53 Subpart D. Appendix J specifies inertial separation of particle sizes and collection on pre- and post-weighed filters. This precludes automating all but

filter changing in reference methods. There is only one automated reference method on the current list of designated reference and equivalent methods -- a sampler that substitutes automated filter sequencing for manual filter changes. There are several automated equivalent methods based on the principles of beta attenuation and the TEOM.

Candidate automated methods for CO, O₃, and NO₂ must utilize the measurement principles established in 40 CFR 50 (Appendices C, D, and F respectively) and meet the testing requirements of 40 CFR 53 Subpart B. Since the Part 50 principles for CO and NO₂ (NDIR and gas phase chemiluminescence, respectively) have proven to be simple and reliable, there are many reference methods and relatively little development of alternate analytical principle requiring the monitors to be certified as equivalent methods. The ozone analytical principles; however, are based on ethylene chemiluminescence. The most widely used analyzers use NDUV which does not require ethylene gas cylinders. Therefore, there are relatively more equivalent methods than reference methods.

The design and performance requirements and operational requirements applicable to reference methods for PM_{2.5} samplers are specified in Appendix L of 40 CFR 50. These requirements are quite specific and include explicit design specifications for the type of sampler, the type of filter, the sample flow rate, and the construction of the sample collection components. However, various designs for the flow-rate control system, the filter holder, the operator interface controls, and the exterior housing are possible. Hence, various reference method samplers from different manufacturers may vary considerably in appearance and operation.

Equivalent methods for PM_{2.5} have a wide latitude in their design, configuration, and operating principle. Three classes of equivalent methods have been established in 40 CFR 53 based on the candidate method's degree of deviation from the reference method principles. All three classes of PM_{2.5} equivalent methods are acceptable for SLAMS (or SLAMS-related) PM_{2.5} sampling.

Class I equivalent methods are very similar to the reference methods, with only minor deviations. These methods meet nearly all the reference method specifications and requirements and operate very much the same as reference methods. The requirements for designation as a Class I equivalent method are only slightly more extensive than reference method testing.

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Class II equivalent methods are filter based collection methods that differ more substantially from the reference methods than Class I methods. Testing of these methods for certification as an equivalent method is more extensive than testing for Class I methods.

Class III equivalent methods have profound differences from the reference method. This class includes the automated and semiautomated $PM_{2.5}$ monitors and potential new measurement technologies. Certification of a Class III instrument is considerably more extensive than reference method instruments, Class I equivalent methods, or Class II methods.

403.2 CALIFORNIA AIR RESOURCES BOARD REFERENCE AND EQUIVALENT METHODS

The ARB conducts an independent evaluation of ambient air monitoring methods to evaluate their applicability in California. In general, the ARB accepts the EPA methods. However, the ARB feels that their separate evaluation provides an additional level of assurance that the method and equipment will provide the best possible data.

403.3 PARTICULATE MATTER

The equipment used for particulate matter sampling/monitoring depends on the size and type of particulate being sampled and whether time averaged filter samples are to be collected or if a continuous monitor will be used.

403.3.1 Total Suspended Particulate (TSP)

Total suspended particulate sampling for general particulate mass loading is rarely conducted today, having largely been superseded by PM_{10} sampling. Most often when TSP samples are collected it is for the further chemical analysis of particulate lead, sulfate, chromium, etc.

Samples are collected on a one day in six schedule; although samples may be collected more frequently (one day in three or daily) in specific projects or under circumstances that warrant more frequent samples. Each sample is collected for 24 hours from midnight to midnight.

Total suspended particulate is determined by high-volume (HiVol) sampler. The sampler flow rate (1.1 to 1.7 m^3/min [39 to 60 ft^3/min]) and the geometry of the

shelter determines that particles up to 25 to 50 μm aerodynamic diameter are collected depending on the wind speed. This has been found to be true for winds between 1.3 and 4.5 m/sec (3 to 10 miles per hour).

The flow rate of the sampler may be controlled by a mass flow controller or by volumetric flow control. The mass flow controller is a hot wire anemometer which measures the air velocity by sensing the cooling effect of the mass of air flowing past a heated wire. The temperature of the wire and its electrical resistance change because of this velocity-dependent cooling. The temperature of the

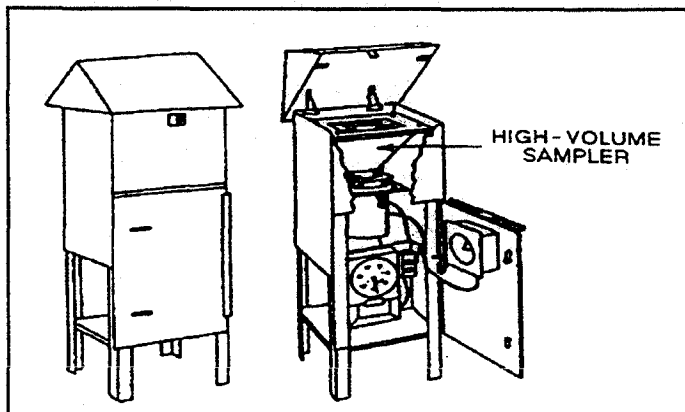


Figure 403.1 HiVol Sampler for TSP Collection

sensing element must be compensated for the ambient air temperature and periodically calibrated. The signal from the sensor may be used in an electronic feedback circuit to adjust the voltage applied to the motor to control the sampling flow.⁶

A volumetric flow controller is a critical nozzle.

Using a volumetric flow controller requires that a larger sampler motor be used to pull a strong vacuum on the downstream side of the nozzle. When the absolute pressure downstream of the nozzle is less than 0.53 of the upstream absolute pressure the velocity in the throat is the speed of sound. A further reduction in downstream pressure cannot increase the throat velocity unless a special supersonic throat is used. Without the supersonic throat, the velocity, and hence flow, is locked and invariant so long as the downstream vacuum remains strong. The motor speed variations may alter the downstream vacuum; however, the flow remains constant.⁶

The sample is collected on a 20.3 x 25.4 cm (406 cm^2 nominal exposed area) glass fiber filter. The filter is weighed prior to sample collection and reweighed after collection. The net mass gain divided by the total air flow during the sampling period gives the average particulate concentration. Additional filter specifications can be found in 40 CFR 50, Appendix B.²⁰

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The HiVol sampler itself (Figure 403.1) is designed to securely hold the filter, provide a means of adjusting and controlling the air flow, and provide a record of the sampler operation. In addition, the geometry of the sampler must hold the filter in a horizontal position at least 1 meter above the sampler support surface. The area of the sampler air inlet must be sized to provide an effective particle capture air velocity of 20 to 35 cm/sec (ideally, 25 ± 2 cm/sec) at the recommended operational flow rate.

The HiVol method has a relative standard deviation precision for a single analyst of 3.0 percent (3.7 percent for interlaboratory precision). The absolute assurance of the method is undefined because of the complex nature of atmospheric particulate matter and the difficulty in determining the "true" particulate matter concentration.

The specific procedures for operation of the HiVol sampler should be in the operating agencies SOP/QA manual. In general, there are three steps to preparing for the sampling run and three steps in retrieving the sample:

Preparing for the sampling run - Loading a filter into the HiVol sampler should be done as close to the sampler start time as practical (see sources of error, below). Since the sampling time is from midnight to midnight, that is usually at least seven hours before sample run start. Prior to the run the operator should obtain the required filter and data forms from the laboratory and station information section, sampling date information, and record the filter number to be used.

Clean filter installation - Upon opening the sampler, the operator should do a once over inspection of the sampler condition and remove any accumulated dust, spider webs, etc. Remove the faceplate, place the filter on the face of the instrument, and replace the faceplate. Carefully tighten the fasteners. (Undertightening will allow air to leak and overtightening will damage the rubber faceplate gasket.) Some HiVols use a filter cassette which can be preloaded in the office. These filter cassettes are especially convenient on windy days when the filter may blow away or be whipped and torn by the wind. The filter cassette is simply fastened in place in the same manner as the faceplate. After installing the clean filter, close the top of the sampler before checking the flow rate.

Set and verify the initial flow rate - Prior to the sampling run the initial flow rate must be checked, reset if necessary, and recorded. Most commonly this is done with a Dickson-type flow recorder. A clean flow chart is placed on the recorder,

lining up the tab on the paper chart with the slot on the recorder and rotating the chart to line up the start time with the pen. Check to see that the pen will start its trace at the proper time and at 0 CFM, tap the recorder lightly to verify that the pen is free and making a legible mark. Turn on the sampler and allow to warm up for approximately five minutes. Verify that the sampler is operating at the proper flow rate, adjust if necessary. The acceptable flow rate range is 1.1 to 1.7 m³/min (39 to 60 cfm) the flow rate may need to be adjusted for the seasonal average temperature and the average barometric pressure at the site. The seasonal average temperature can be obtained from the nearest weather station and the average barometric pressure may be calculated from the station elevation using the following equation:

$$F = 1.001 \times \exp(-0.0001217 \times E)$$

where E = the elevation of the station is in meters, or:

$$F = 1.001 \times \exp(-0.0000371 \times E)$$

Where E = the elevation is in feet.

The desired flow rate should be multiplied by the altitude correction factor.

Timer setting - On manual clock type timers verify that the correct current time is set and place the on and off trip tabs at midnight to midnight on the proper operating day. Be sure that the on tab is set at the on time and the off tab at the off time; the tabs are different and the sample will not operate properly if the tabs are reversed. If an electronic timer is used, set the proper switches/program to start and stop the sampler at the appropriate times. If the sampler has an elapsed time meter, record the starting elapsed time reading.

The sampler now should be closed and secured for the sampling run. The operator should return to recover the exposed filter as soon after the sampling run as practical. The recovery process can also be divided into three principal steps:

Check the post-sampling flow rate - Before opening the top of the sampler or removing the filter and flow chart, make sure that the recorder trace shows the final flow rate. If not, the sampler must be started and the final flow determined. Remove the flow chart from the recorder and examine for abnormalities. Note and investigate any abrupt changes in flow rate or excessive overall flow rate changes.

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If an elapsed time meter is used, record the end time reading and compare it to the start time reading. Also examine the flow chart for the elapsed sampling time. The elapsed time indicated by the meter and the flow chart should be in agreement, if not, investigate the causes. The acceptable elapsed time for sampling is 24 ± 1 hours. The start time must be after 23:30 and the end time must be before 00:30.

Remove the exposed filter - Remove the faceplate from the top of supporting screen. Fold the filter in half with the exposed side inward and place in an envelope or folder for return to the laboratory. An acceptable filter has a uniform white border, a soiled streak into the border indicates an air leak which invalidates the sample. Air leaks may be caused by improper tightening of the fastening wingnuts or by a worn gasket. Any insects on the filter should be carefully removed with tweezers.

Record sampling conditions - Record on the sampling record form the sample date, start and end times, weather conditions, and initial and final flow rates indicated by the flow chart. Using the sampler calibration curve, convert the flow readings to true flow and record.

There are a number of inherent source of error with this method; with proper site selection and proper operation these potential biases can be minimized or eliminated.

Airflow variation - The weight of the mass collected on the filter represents the integrated sum of the instantaneous TSP concentrations and sampler flow rates during the sampling period. Dividing the total mass by the average flow rate results in the true average particulate matter concentration only when the flow rate has been constant throughout the sampling period. The resulting error depends on the magnitude of the instantaneous particulate concentration and the degree of over or under collection.

This can be a more complex problem than it first appears since there is an intricate interaction between the flow rate and the particulate cut off at the sampler inlet. For example: a temporary high flow rate would draw more air and, hence, more particles into the sampler; however, at high flow rates the inlet would have a finer cut off point (i.e. relatively coarse particles that normally would be collected may be excluded). Therefore, the high flow rate may bias the collected mass low and the integrated flow rate high. Resulting in an average sample doubly biased low. Low flow may result in the opposite situation.

Air volume measurement - If the flow rate changes substantially or nonuniformly during the sampling period, appreciable error in the estimated air volume may result from using the average of the presampling and postsampling flow rates. Improved air volume accuracy may be achieved by using a flow controlling device, a calibrated flow recorder, or some other means of accurately determining the air volume throughout the sampling period. Most HiVol samplers are equipped with both a flow controller and a recorder.

Loss of volatiles - Volatile particles collected on the filter may be lost during subsequent filter handling and storage. Significant fractions of the nitrate and organic²¹ particulate collected on the filter can be lost by this means.

Loss of volatile particles can significantly bias samples low. To prevent losses, the filters should not be exposed to high temperatures (if possible) and postweighed as soon after sampling as practical. Volatile particles can also be lost during sampling due to the vacuum and temperatures on the filter. To some extent, loss of volatile particles is unavoidable, just as is the gain of some artifact particles, but with care it can be minimized. To help minimize volatilization, filters must be equilibrated in a constant temperature environment (between 15°C and 30°C, $\pm 3^\circ\text{C}$).

Artifact particulate matter - The most common artifact particulate matter is the result of the reaction of acid gases (SO_2 , NO_x , etc.) with alkaline glass fiber filters and alkaline particles that have been collected on the filter. This results in higher than true particulate measurements. In many cases, such fine particulate matter is the sink of the acid gases; however, that particulate matter would form farther downwind, i.e. it would form part of the ambient particulate loading at some other location. Organic gases can also form artifact particulate matter.²²

The effect of artifact formation is generally minor. In areas of high acid gas or reactive organic gases that may tend to form artifacts, a denuder may be useful to remove the gases before collecting the particulate on the filter.

Humidity - Glass fiber filters used for most particulate collection are relatively insensitive to changes in relative humidity. However, the particulate matter collected on the filter can be quite hygroscopic. Therefore filters must be equilibrated at a constant, known, humidity. The equilibration conditions should be constant at a relative humidity below 50% $\pm 5\%$. Under these equilibration conditions samples collected at low RH will gain moisture to standard condi-

tions and those collected at high RH will lose moisture to the standard conditions.

Filter handling - Careful handling of the filter between the presampling and postsampling weighings is important to avoid errors due to the loss of particles or fibers and fragments of the filter. A paper sleeve or cassette can be used to protect the filter during handling to minimize errors.

Nonsampled particulate matter - Particulate matter may be deposited on the filter when the sampler is inoperative. Between the time when the filter is loaded into the sampler and the sampling run actually begins is an opportunity for extraneous particulate matter to be blown into the sampler, resulting in a positive bias. The opportunity for bias also exists after the sampling run, but before the exposed filter is retrieved and sent to the laboratory. This extra mass is particularly important on windy days in dry environments. These errors can be minimized by the use of an automatic mechanical device that keeps the filter covered during the nonsampling periods and opens to expose the filter during the sampling run.

Timing errors - Samplers are normally controlled by clock timers set to start and stop the sampler at midnight. Errors in the nominal 1440 minute sample time may result from: poor resolution of the set-points, missetting the timer, timer error due to power failure, or timer malfunction. Digital timers have much better set-point resolution and reliability, but a backup battery must be supplied. A continuous flow recorder or an elapsed time meter provides an indication of the sampler run-time, as well as an indication of any power interruption during the sampling period and is therefore recommended.

Recirculation of sampler exhaust - During stagnant wind conditions, sampler exhaust air can be resampled. This problem can be resolved by ducting the exhaust away from the sampler, preferably in the predominant downwind direction. A related problem on poorly located samplers at a station where more than one sampler exists is that of the downwind sampler sampling the exhaust of the upwind one. This condition is obvious from an analysis of the filters; if a sampler is resampling exhaust the concentration of carbon and copper on the filter will be significantly higher.

403.3.2 PM_{10}

Since the 1980's the NAAQS for particulate matter has been based on PM_{10} (particles with an aerodynamic diameter less than or equal to 10 micrometers) rather than the older TSP particulate matter. Although there are other methods, the four principle measurement techniques are: size selective inlet hivol sampler (SSI), dichotomous sampler (dichot), tapered element oscillating microbalance (TEOM®), and beta attenuation monitoring (BAM).

SSI HiVol

The size selective inlet hivol is a variant of the TSP hivol discussed in Section 403.3.1 with the addition of the inertial particle size selective inlet (Figure 403.2). The inlet consists of a series of acceleration tubes, impaction plates, and vent tubes that force the inlet air to make rapid changes in direction. In these rapid changes the particles with an aerodynamic diameter larger than 10 micrometers impact on the impaction plates and are removed from the air stream.

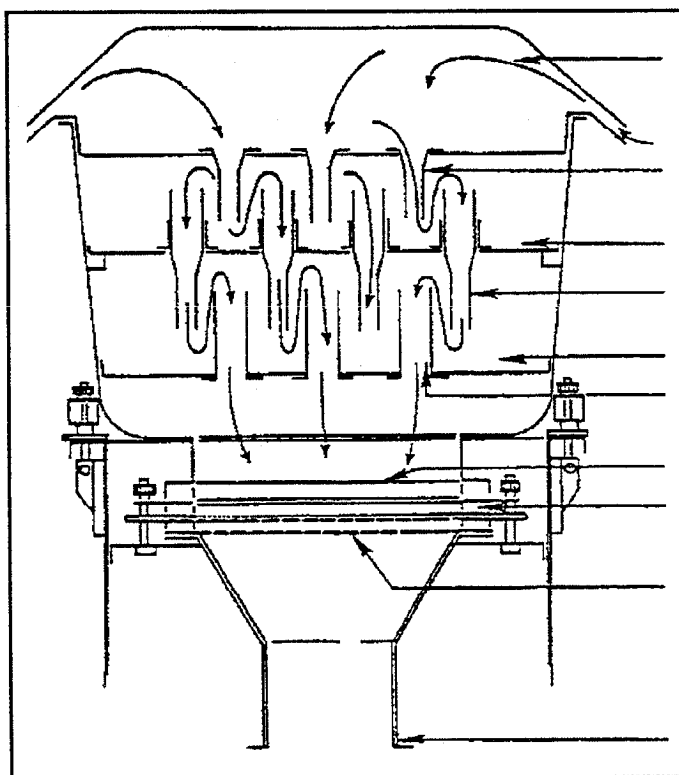


Figure 403.2 SSI HiVol

The particle size separation is critically dependent on the air flow. For this reason, the flow control of SSI PM_{10} samplers must be well controlled. The sampler flow rate must be maintained at $1.13 \text{ m}^3/\text{min}$ (40 cfm) $\pm 10\%$ (i.e. 1.02 to $1.24 \text{ m}^3/\text{min}$ [36 to 44 cfm]). The flow rate that is important for the inlet is the actual flow rate, rather than the flow rate corrected to standard conditions.

If the flow rate increases substantially, the velocity in the acceleration jets increases, causing more severe selection conditions; resulting in removing some of the larger PM_{10} particles, biasing the sample low. On the other hand, low flow rate will allow too many large particles through the size selective inlet, biasing the sample high.

Dichot

The dichot (dichotomous) sampler, as its name implies, divides the sample into two size fractions: between $2.5\mu m$ and $10\mu m$ and less than $2.5\mu m$. The sum of the two fractions gives the PM_{10} concentration. The filters used in the dichot are 37 mm diameter teflon filters.

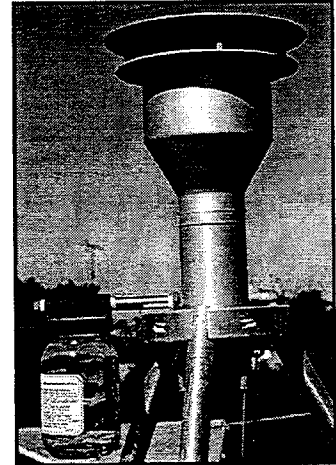


Figure 403.3
Medium Flow PM_{10}
Inlet

The dichot sampler uses a medium flow PM_{10} inlet (Figure 403.3) at 16.7 lpm flow rate. The unique process about the dichot sampler is that it splits the sample stream into the two particle size fractions. To accomplish this it uses a virtual impactor (Figure 403.4). In the virtual impactor the majority of the air flow, entraining the fine particles, is diverted in a small gap and the particles collected on the fine fraction filter. The inertia of the larger particles is too great to make the diversion and are collected on the coarse fraction filter.

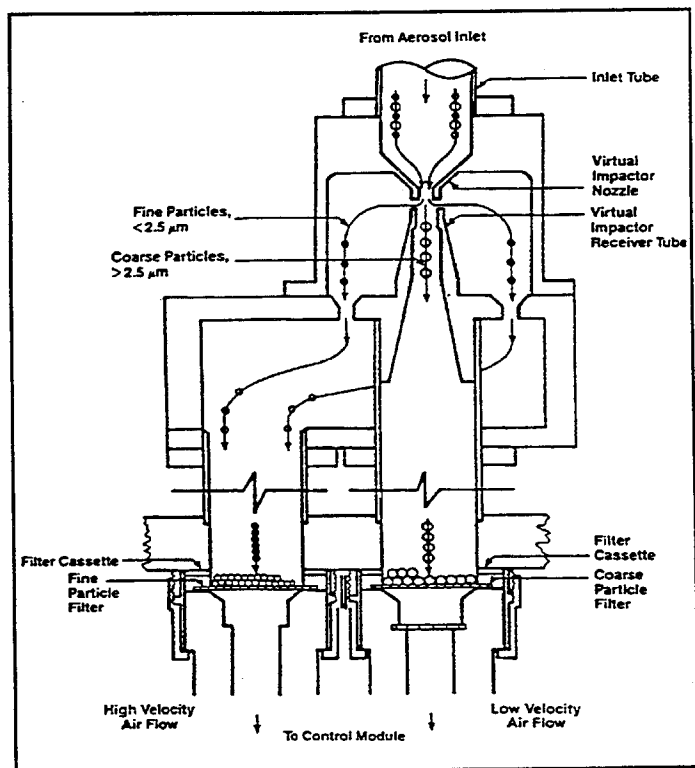


Figure 403.4 Dichot Virtual Impactor
Particle Size Fractionation

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Ambient Air Monitoring

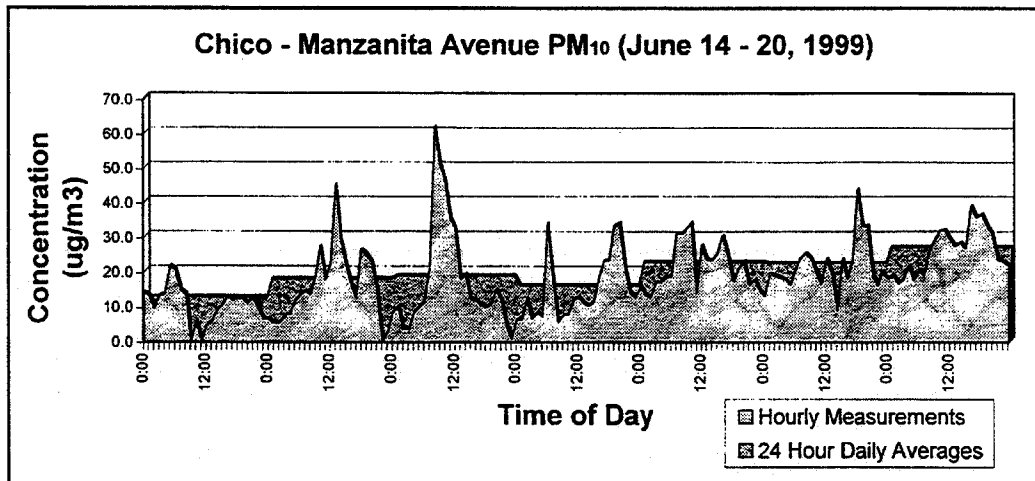


Figure 403.5 Comparison of Daily and Continuous Particulate Matter Sampling

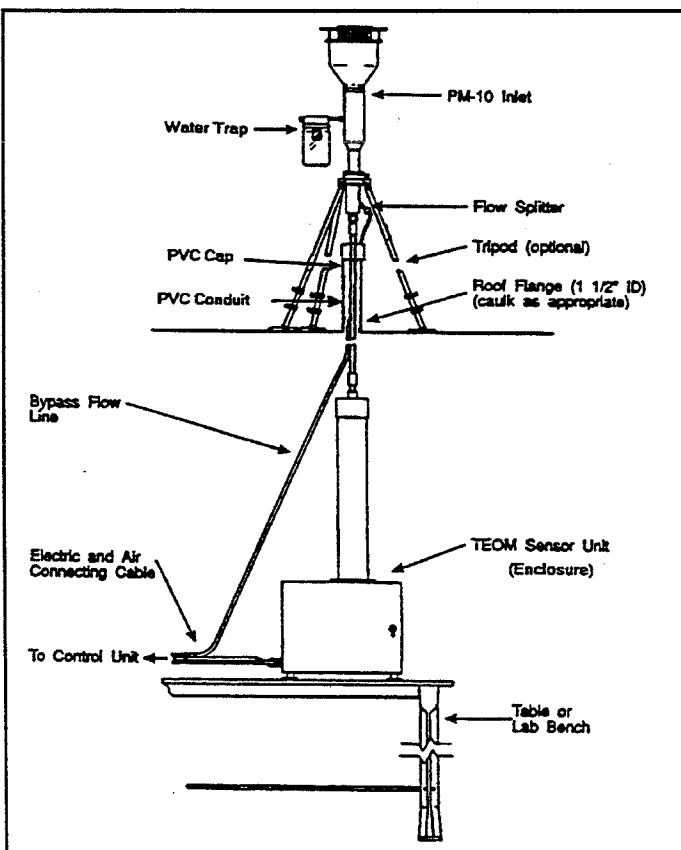


Figure 403.6 TEOM® Continuous Particulate Matter Monitor

TEOM®

The Tapered Element Oscillating Microbalance (TEOM® Rupprecht and Patashnick Co., Inc.) gives a continuous readout of the ambient particulate matter concentration. A continuous measurement of particulate matter gives vastly more information (i.e. meteorological changes and transient phenomena) than conventional daily averaged filter samples (Figure 403.5). In addition, a continu-

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ous monitor can be linked via telephone lines to transmit real-time data to a central office.

The TEOM continuously monitors particulate matter by capturing the particulate on a filter attached to a vibrating inertial mass transducer (see Section 402.4.2). Changes in the vibrational frequency correspond to the mass of particulate captured.

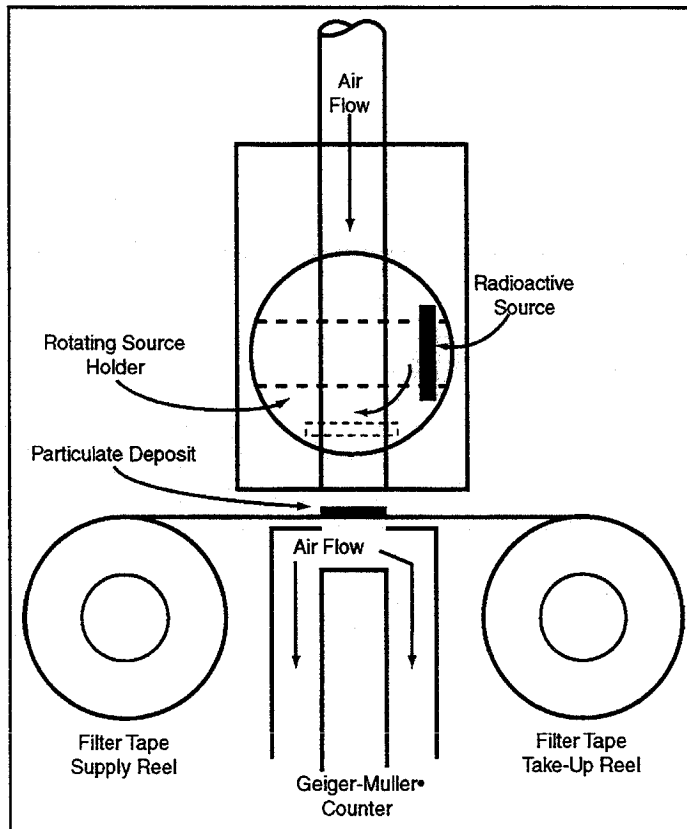
The TEOM sampler (Figure 403.6) uses a standard medium flow PM_{10} inlet to select the PM_{10} fraction from the total ambient particulate. The sampler uses only 3.0 liters per minute of the total of 16.67 lpm inlet flow, the remaining flow required by the inlet passes through a bypass flow line. Two factors of primary concern in the placement of the unit are the need for a sturdy, vibration-free mounting (i.e. a vibration-free table) and a straight vertical access to the roof for the sample probe. The sample probe consists of a length of polished stainless steel tubing. Vibration shielding is important to prevent interference with the frequency of the vibrating microbalance. The bypass flow line consists of a length of flexible tubing to the vacuum pump. The chamber in the monitor that contains the microbalance is heated to prevent condensation and to stabilize the frequency readings which are effected by changing temperatures.

The TEOM requires periodic flow calibrations; however, it never requires mass calibration.

BAM

The beta attenuation monitor (BAM) continuously measures particulate matter concentrations by monitoring the attenuation of transmission of beta radiation through the filter and collected particulate deposit. In principle, the monitor operates by the absorption of low energy beta radiation by collision with electrons whose number is proportional to the density of the deposited particulate matter. Measurement of the absorption of the tape before and after deposition overcomes any problems that may occur due to filter heterogeneity. BAM instruments also often compensate for temperature variations.

The instrument operates by sequentially collecting particulate matter on an area of the filter tape and measuring the density of the deposit (Figure 403.7). At the end of each collection period the radioactive source rotates into position at the center of the deposited particulate matter and in front of the Geiger-Muller (GM) counter tube. The mass of collected particulate matter is related to the ratio of the first beta count (before particulate collection) to the second:



$$m = K \times \ln\left(\frac{N_1}{N_2}\right)$$

Where the K value is determined when the span operation is memorized by the instrument.

The measurements are conducted such that a zero reading is an integral part of each sample. This integral zero and the stability of the GM tube makes calibration of the measurement system unnecessary. Periodic calibration and audits of the volumetric flow control are; however, needed.

Figure 403.7 BAM Sampler Operation²³

403.3.3 PM_{2.5}

Essentially, to collect PM_{2.5} one could use technology similar to PM₁₀, but with more severe particle separation conditions to reduce the cut point particle size to 2.5 μm. In practice; however, the introduction of PM_{2.5} sampling was seen as an opportunity to initiate new and more sophisticated technologies. Through comparison of new data with collocated data from dichot sampler fine fraction, IMPROVE samplers, etc., data from those existing, long-term data sets may be useful for decision making and network design.

The PM_{2.5} air monitoring program consists of three major measurement components: mass, routine speciation, and special chemical speciation studies.²⁴ The mass measurement portion is used primarily to obtain data for comparison with the PM_{2.5} NAAQS and related activities.

The routine speciation portion will provide a national picture of various particulate matter constituents for both long-term trends and short-term data assessment

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needs. The specific sampling techniques and schedules will be determined by the agencies using the data.

The special chemical speciation studies will provide additional data for a more complete national picture of ambient particulate matter and for confidence in the SIP development and implementation status. These studies are designed to concentrate on those four to seven areas of the country with distinct particulate matter problems. For example, one of these regions may be the southwestern US area that is potentially impacted by the Los Angeles, Phoenix, Las Vegas, and San Joaquin Valley airsheds. Each study region also have subregions with a variety of airshed characteristics. Data collected in the special chemical speciation portion of the $PM_{2.5}$ networks, supplemented with data from the mass and routine speciation portions, will be useful in understanding particulate matter pollution for all areas of the country.

As of this writing, there are eight reference methods listed by the EPA. The reference method $PM_{2.5}$ samplers collect their sample over a 24-hour period on Teflon-membrane filters from air drawn through a certified $PM_{2.5}$ inlet at a controlled flow rate. The inlet and size separation components are specified by design, with drawings and components and procedures are specified by performance characteristics, with specific test methods to assess that performance.

403.3.4 Coefficient of Haze (COH)

The coefficient of haze is an indirect measurement of ambient particulate matter concentrations. The COH units can be used to assess mass concentrations of particulate matter through empirical relationships which must be developed for the specific location, generally through a collocated gravimetric device such as a Hi-Vol sampler.

The Research Appliance Corporation (RAC) soiling index tape sampler (American Iron and Steel Institute [AISI] tape sampler) is used by the Air Resources Board to measure the COH. The AISI tape sampler is similar to the BAM; however, the AISI measures the collected particulate matter by attenuation of visible light. The COH units are determined as the optical density (OD) of the deposit, i.e.: "that quantity of particulate which produces an OD of 0.01 on the filter tape." The AISI sampler draws air at a rate of 6.25 liters per minute and filters the particulate matter through a one inch area. A light source above the tape and a photocell below the tape measures the decrease in light transmission as the particulate deposit accumulates. The flow rate provides a one to one

linear relationship between COH units and transmission (T) from 100% to 78% of the chart. The opacity of the filter spot is continuously determined and the percent transmittance related to COH units per 1000 linear feet of ambient air.

$$\text{Optical density (OD)} = \log_{10} \frac{100}{\%T} \frac{(\text{new tape transmittance } \%)}{(\text{sample spot transmittance})}$$

$$\text{COH units/1000 ft} = \frac{(\text{OD}) \times (10^5)}{L}$$

Where L is the total linear feet of air drawn through the filter paper and the one inch circle spot on the filter paper, in square feet, is $5.45 \times 10^{-3} \text{ ft}^2$:

$$L = \frac{\text{Sample time (minutes)} \times \text{air flow rate (CFM)}}{\text{Sample spot area (square feet)}}$$

After the filter spot has collected particulate matter for two hours, the tape advances to begin collecting on a fresh spot. At this rate of sampling, the tape roll will last approximately 60 days.

403.3.5 Lead

In the past, airborne lead was principally derived from lead in automotive fuel. Today, since lead has been removed from gasoline, stationary sources are the predominant sources. Since the sources of lead have changed and are fewer, fewer lead sampling stations are needed in the field.

Lead is analyzed as a component of particulate matter. Typically, most lead is associated with fine particulate matter. The lead containing particulate is collected by Hi-Vol sampler (see TSP, Section 403.3.1). The reference method of analysis is an acid digestion of the particulate on the filter and analysis by atomic absorption spectrometry using an air-acetylene flame. The EPA equivalent methods for lead also use Hi-Vol collection, but use alternative methods for analysis.

403.4 OZONE

In the reference method for ozone measurement the ambient air is reacted with ethylene. This reaction emits light which can be detected by a photomultiplier tube.²⁰ In most ambient monitoring applications; however, the UV photometric

method is used rather than the ethylene method. Measurement of ozone by the photometric method is generally more convenient since it does not require tanks of pressurized ethylene.

In the UV photometric method (Figure 403.8) ozone is measured by the attenuation of UV radiation at 254 nm due to internal electronic resonance of the ozone molecule. Light from the lamp shines down a hollow glass tube that is alternately filled with sample gas (ambient air), then filled with gas that has been scrubbed of ozone. The ratio of the intensity of light passing through the scrubbed gas to that of the sample forms a ratio I/I_0 . This ratio forms the basis of calculating the concentration of ozone by the Beer-Lambert equation.

Where:

Beer-Lambert equation:

$$C_{O_3} = -\frac{10^9}{\alpha l} \times \frac{T}{273 \text{ K}} \times \frac{760 \text{ mm Hg}}{P} \times \ln \frac{I}{I_0}$$

I = the intensity of light passing through the sample gas

I_0 = the intensity of light passing through the scrubbed gas

α = absorption coefficient

l = sample cell path length

C_{O_3} = concentration of ozone in ppb

T = the temperature in Kelvins

P = pressure (mm Hg)

As can be seen, the concentration depends on more than the intensity ratio.

Temperature and pressure can greatly affect the concentration by influencing the

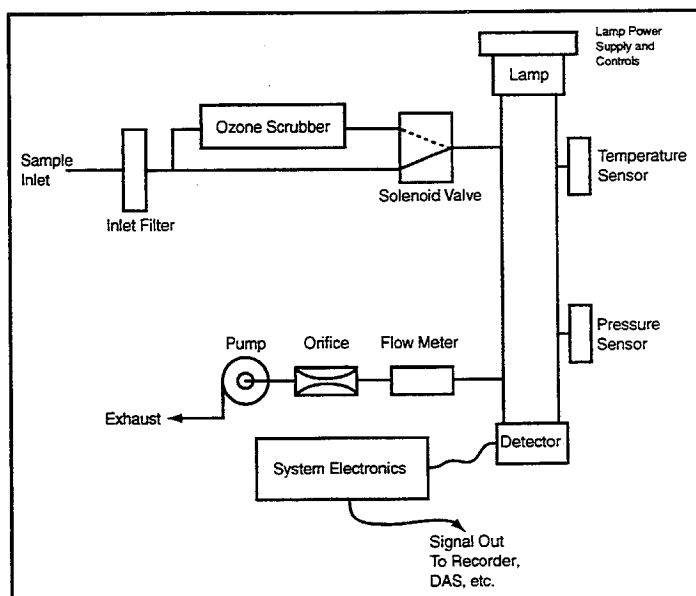


Figure 403.8 Photometric Ozone Analyzer

density of the gas. The density changes the number of molecules in the absorption tube which impacts the amount of light absorbed from the light beam. Therefore, it is important to calibrate the analyzer for the elevation at which it will operate. This is particularly true at elevations above 300 meters (1000 ft). Audits and calibrations must also be conducted in a manner that does not pressurize the system. It is also important that the monitoring station remain within temperature limits.

The absorption coefficient is a number that reflects the inherent ability of ozone to absorb 254 nm UV light. Most current measurements of α place it at $308 \text{ cm}^{-1} \text{ atm}^{-1}$ at STP.

The intensity of light is measured by a detector that converts the light into a voltage. Since the ambient air sample is alternated with scrubbed air, an alternating signal generated by the system which can be more reliably measured than a constant signal and includes a zero value. Repeated measurements of I_0 also minimize instrument drift due to changing intensity of the lamp due to aging and dirt.

The process sequence of the API 400 Ozone Analyzer is typical of these instruments. In this sequence every eight seconds the analyzer completes a measurement cycle consisting of a two second flush of the sample tube with sample (i.e. ambient) air followed by a two second measurement period when the attenuated light intensity is measured (I). For the next two seconds the sample tube is flushed with scrubbed (ozone free) air, followed by a two second measurement period (I_0). The process then repeats.

Photometric ozone analyzers can be subject to a number of interferants. The principal interferant that can be controlled by the operator is particulate matter. The inlet filter protects the sample cell from ambient particulate and should be regularly changed. Particulate matter in the sample cell will react with and remove the sampled ozone, resulting in a sample biased low. In addition, high levels of SO_2 , NO_x , water, and volatile aromatic hydrocarbons can interfere with ozone measurements.

Ozone analyzers often incorporate a calibration subsystem. When included, this subsystem generates ozone (typically by a high-intensity UV lamp), adjusts the concentration to the desired level, and feeds it into the analyzer through the sample inlet. The calibration subsystem contains a separate, reference detector for comparison to, and calibration of, the analyzer detector.

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403.5 CARBON MONOXIDE (CO)

Reference methods for CO measurements are based on non-dispersive infrared photometry. The approved reference methods for CO are either gas filter correlation or conventional NDIR instruments. A detailed description of these analytical methods is contained in Sections 402.1.3 and 402.1.4. Audits and calibrations of CO instruments are generally conducted using certified cylinders of compressed gases. The cylinders may contain either a high concentration of CO and diluted to the working concentration or may contain the working concentration and used without dilution. For specific calibration and audit procedures, operators should refer to their manual of SOPs.

403.6 NITROGEN DIOXIDE (NO₂)

Atmospheric concentrations of nitrogen dioxide (NO₂), the regulated species of nitrogen oxides, is measured indirectly by photometrically measuring the light produced by the reaction of nitrogen oxide (NO) with ozone (i.e. by chemiluminescence). To determine NO₂ in this manner requires a three step process: 1) the total concentration of all nitrogen oxides (NO_x) must be measured; 2) the concentration of nitrogen oxide must be measured; and 3) the nitrogen dioxide is calculated as the difference between the total NO_x and NO measurements (see Section 402.1.6)

The Environment S.A. AC31M analyzer combines the NO and total NO_x analysis steps by splitting the sample and passing part through a molybdenum converter oven. This instrument has two measurement chambers, one for NO and one for NO_x) and a single detector. A segmented chopper alternates the detector signal between the NO chamber, the NO_x chamber, and a zero (opaque) measurement (Figure 403.9).

The reference methods approved by the U.S.EPA are chemiluminescent analyzers. In addition, there are several manual equivalent methods that use a sodium arsenite absorber solution to collect NO₂ in a bubbler type sampler. There is also an automated equivalent method that uses an open path type instrument. The open path method measures NO₂ over a path from 50 to 500 meters long.

Chemiluminescence NO/NO₂/NO_x analyzers will respond to other nitrogen containing compounds, such as peroxyacetyl nitrate (PAN), which might be reduced to NO in the thermal converter. Atmospheric concentrations of these compounds are generally low enough, relative to NO₂, so as to not pose a sig-

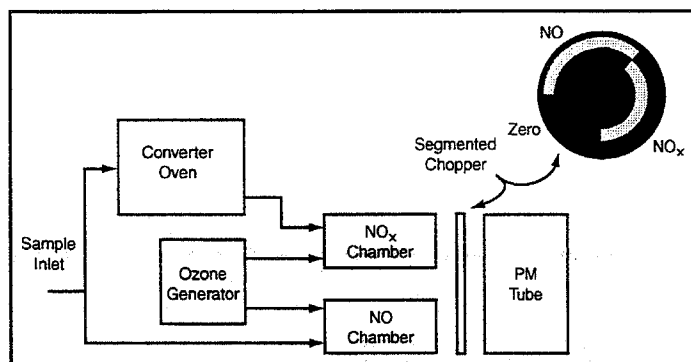


Figure 403.9 Simultaneous NO and NO_x Measurement Method (Environment S.A. AC31M)

nificant source of error to the NO₂ measurements. If concentrations of potentially interfering nitrogen compounds is suspected, an alternate or equivalent method should be used. The sample residence time between the sampling point and the analyzer should be kept to a

minimum to avoid the reaction of ambient levels of NO and O₃ in the sampling system.

The use of particulate filters on the inlet of the analyzer helps to protect the optics of the instrument from contamination and are required by the CARB. However, the U.S.EPA reference methods leave particulate filters up to the operating agency's option. Users of particulate filters must be cautioned; however, that particulate matter on the filter may cause erroneous NO₂ measurements and therefore the filters must be frequently changed.

The ozone generator is an integral part of the chemiluminescent NO_x analyzer. It must generate sufficient and stable levels of ozone for complete reaction of any foreseeable NO concentration. Ozone generators that use an electric discharge to produce the ozone can also produce NO and NO₂ from the dry air feed and should be avoided.

403.7 HYDROCARBON ANALYZERS

Hydrocarbons (HCs) are not a criteria pollutant and, as such, the U.S.EPA does not maintain a list of designated reference and equivalent methods. Therefore, more latitude is available to agencies monitoring HCs. If an agency is going to monitor HCs as part of an ozone control program or a toxics program, they should include a section in their SOPs about which HC monitor to use and the operating practices. The ARB uses the TECO 55C Hydrocarbon Analyzer. This instrument uses a gas chromatographic column and a flame ionization detector (FID) to provide quantitative analysis of ambient levels of methane (CH₄), total hydrocarbon (THC), and total non-methane hydrocarbons (TNMHC).

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The analytical cycle begins by purging a sample loop with carrier gas (purified air). The sample is moved by the carrier air to a tee where it is split into samples to be analyzed for THC and methane. The THC sample moves through a flow balancing capillary to the FID whose output is proportional to the number of carbon atoms present. The methane sample moves through the chromatographic column which separates the methane from the heavier hydrocarbons and serves to delay the sample so it arrives at the FID after the THC sample has been analyzed. After the Auto Zero function measures the baseline voltage of the FID the sample loop is purged with ambient air for the next sample and the analytical column is backflushed with clean air to remove the heavier hydrocarbons that were separated from the methane in the measurement cycle. The analytical cycle then repeats.

A slightly different analytical procedure is used in the Environment S.A. HC51M hydrocarbon analyzer. This analyzer distinguishes between total and nonmethane hydrocarbons by a selective converter oven to oxidize all the hydrocarbons except methane. The nonmethane hydrocarbon measurement is the difference between the total and converted (methane only) measurements.

Since compressed hydrogen gas is used in the FID, extra caution (beyond that needed when handling all compressed gas cylinders) due to the flammable nature of the hydrogen. Only clean regulators with teflon or stainless steel diaphragms and seats should be used to prevent contamination of the compressed calibration gases. In place of compressed cylinders of hydrogen a hydrogen generator may be used to produce the hydrogen as needed.

403.8 SULFUR DIOXIDE (SO₂)

The reference method for SO₂ is a manual procedure in which ambient air is bubbled through an absorber solution and the concentration of SO₂ collected measured by a colorimetric analysis. The absorber is a 0.04 M solution of potassium tetrachloromercurate (TCM) which forms a stable monochloro-sulfonato mercurate complex. The solution is then analyzed by reacting it with acid-bleached pararosaniline dye and formaldehyde to form an intensely colored pararosaniline methyl sulfonic acid. The optical density of this species is determined spectrophotometrically at 548 nm. One of the chief disadvantages of this method is the mercury content of the absorber solution which must be handled with great care and properly disposed of.

In practice, automated equivalent methods are almost universally used. Fluorescence analyzers are most commonly used. These analyzers utilize the property of SO_2 that causes it to fluoresce after its absorption of ultraviolet light (see Section 402.1.5). Sulfur dioxide is excited by UV radiation in several wavelength regions. A bandpass filter generally is used to limit the excitation radiation to 190 - 230 nm, a region of minimal quenching and interference by air and most other molecules found in polluted air. A zinc lamp may be used to generate UV light at a wavelength of 214 nm. The peak of SO_2 excitation occurs at about 216 nm. The photomultiplier tube detector is placed at 90° to the excitation beam with a broadband optical filter (240 - 420 nm).

To reduce interferants the sample is dried in a permeation dryer and the aromatic hydrocarbons are removed before the sample is analyzed. Carbon disulfide, nitric oxide, and ethylene fluoresces weakly in the analytical range and some aromatic hydrocarbons fluoresce at the same wavelength as SO_2 or absorb the fluorescent light. The rejection ratio for these is generally greater than 5000:1, therefore these interferences are insignificant except in rare occasions.

In addition, there is an approved automated equivalent method for the use of an open path instrument. The open path monitoring method integrates SO_2 over a path of 20 to 500 meters in length.

403.9 HYDROGEN SULFIDE (H_2S)

Hydrogen sulfide is not a criteria pollutant, therefore, the U.S.EPA does not approve reference and equivalent methods for its determination. The standard method in California is measurement by thermal oxidation and fluorescent analyzer. In this method H_2S is converted in the thermal oxidizer into SO_2 which is measured in a fluorescence analyzer described above. The H_2S results must be corrected for the SO_2 concentration.

Another method of measuring H_2S is with a sensitized filter paper tape (for example the Houston Atlas Model 825R). This is an older method that uses the reaction of lead acetate form a brown stain, which attenuates transmitted light and is proportional to the H_2S concentration. This method is similar to the COH measurement of particulate matter and the BAM method in which particulate matter attenuates beta radiation.

The paper tape method conditions and humidifies the sample by bubbling it through a bubbler containing a 5% acetic acid solution.

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403.10 ACID DEPOSITION

Acid deposition monitoring consists of measuring the acidity and content of acidic components deposited through wet and dry deposition processes. Wet deposition processes are principally rainfall, snow, and fog. Dry deposition consists of the deposition of particulate matter and acidic gases. Wet deposition and particulate matter predominantly deposit by gravitation; however, gases deposit by Brownian motion whereby the random motions of the gas molecules in the atmosphere bring them into contact with surfaces onto which they deposit.

Acid deposition samplers may be divided into active and passive instruments. The passive instruments consist of a pair of buckets; one of which is exposed in clear weather and the other in rainy weather. A cover moves from one bucket to the other (triggered by moisture on a thermistor sensor) to preclude dry deposition accumulating in the wet bucket or wet deposition getting into the dry bucket.

The wet side sample buckets are changed weekly and the dry side buckets are changed every eight weeks. If the wet side bucket fills with snow it should be replaced with an empty bucket and the snow melted and the water collected. All thawed bucket contents should be combined into a single weekly sample. In the case of very heavy rain (i.e. if the wet side bucket accumulates approximately nine inches of rain) the bucket should be replaced. Each bucket will be treated as a separate weekly sample and should be documented accordingly.

The wet bucket contents are analyzed on site for precipitation volume, pH, and conductivity before the contents are shipped to the laboratory. At the laboratory the bucket contents are analyzed for pH, conductivity, sodium, potassium, calcium, magnesium, ammonium, chloride, nitrate, and sulfate.

The sample buckets are extremely sensitive to contamination; even a fingerprint on the inside wall of the bucket can cause an erroneous analysis of the ions. In addition, since the human breath contains enough ammonia to cause an erroneous measurement, the operator must be careful not to breathe into the bucket when servicing the sampler. The use of clean lab gloves is recommended when handling the buckets. Because of the sensitivity of the dry side bucket to contamination, it is not generally used for dry acid deposition measurements, the dry deposition data is generally derived from the active sampling system. The wet side bucket is; however, used for wet acid deposition determination.

The active acid deposition sampler used in California is the CADMP (California Acid Deposition Monitoring Program sampler, Figure 403.11). The CADMP sampler originally used two sampling trains: PM₁₀ and PM_{2.5} units. Only the

PM_{2.5} unit is currently in use. The CADMP collects samples on filters for laboratory analysis. Each filter is run for 12 hours; either during the day (06:00 to 18:00) or during the night (18:00 to 06:00). One channel contains a denuder and nylon filters for particulate nitrate determination. The other channel contains a teflon filter for mass, metals (Na⁺, Mg⁺², K⁺, Ca⁺²), ammonium (NH₄⁺), and ions



Figure 403.11 CADMP Acid Deposition Sampler

(SO₄⁻², NO₃⁻, and Cl⁻) and a nylon filter for total nitrate (sum of nitrate from the nylon filter and the nitrate from the ions filter) measurement. Nitric acid vapors are determined by the difference between the denuded channel particulate nitrate and the total nitrate.

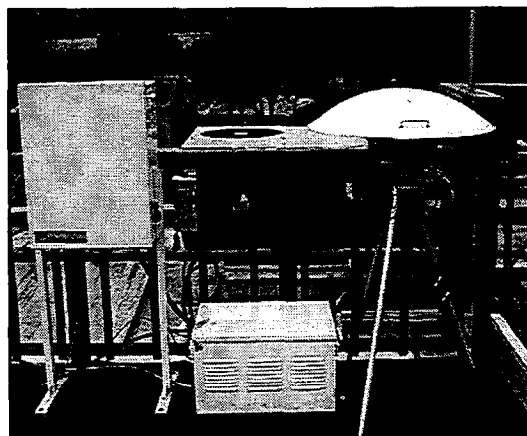
403.11 TOXICS

The methods for collection of samples and analysis for toxic components depend on the form and properties of the pollutant of interest. Toxic particulate matter is collected in the same manner as other particulate samples. The sample is then extracted and/or analyzed in a manner appropriate for that pollutant. For example, heavy metals such as chromium may be sampled on a filter and analyzed by X-Ray fluorescence or extracted and analyzed by atomic absorption. Gaseous toxic pollutants may be collected by adsorption in a sorbent tube and extracted for analysis or collected in an evacuated canister.

403.11.1 Filters and Resins

The Xontech Model 920 sampler (Figure 403.12) is the primary sampler used in California for collecting samples of toxic air pollutants on filters and resin sorbent tubes. The sampler is designed such that eight individually controlled sampling channels can be readily installed. The sampler can precisely control the sampling time and flow rate of each sampling head independently through its microprocessor and set of mass flow controllers.

Each sampling module contains a slider valve and drive motor and a sampling media holder. The filter modules (Figure 403.13a) holds a 37 or 47 mm filter and the sorbent tube modules (Figure 403.13b) hold tubes containing sorbent materials for the specific pollutant of interest. When the microprocessor clock reaches the indicated start time, a signal is sent to the sampling module for the slider valve to open and the solenoid valve of the flow controller to open to allow the sample flow to begin. At the end of the sample period the solenoid valve closes and the slider valve closes to protect the collected sample.



**Figure 403.12 Xontech 920
Toxic Air Pollutant Sampler**

Because of the flow capacity of the instrument, a maximum of four filters and four sorbent tubes may be operated simultaneously. Flow rates for membrane filter samples are typically 10-14 lpm and glass fiber filters 18-20 lpm. The flow rates for sorbent tubes is quite different, typically approximately 0.7 lpm. If the flow rate varies more than $\pm 10\%$ during the sampling run, the run should be voided and a replacement sample collected. The sample time must also be within ± 1 hour of the required time.

403.11.2 Canister Sampling Systems

The canister-type toxic sampling systems collect ambient air samples in SUMMA polished stainless steel canisters for later laboratory analysis. A wide range of organic compounds can be determined by canister sampling; the compounds analyzed are not restricted to those that adsorb onto an adsorbent or can

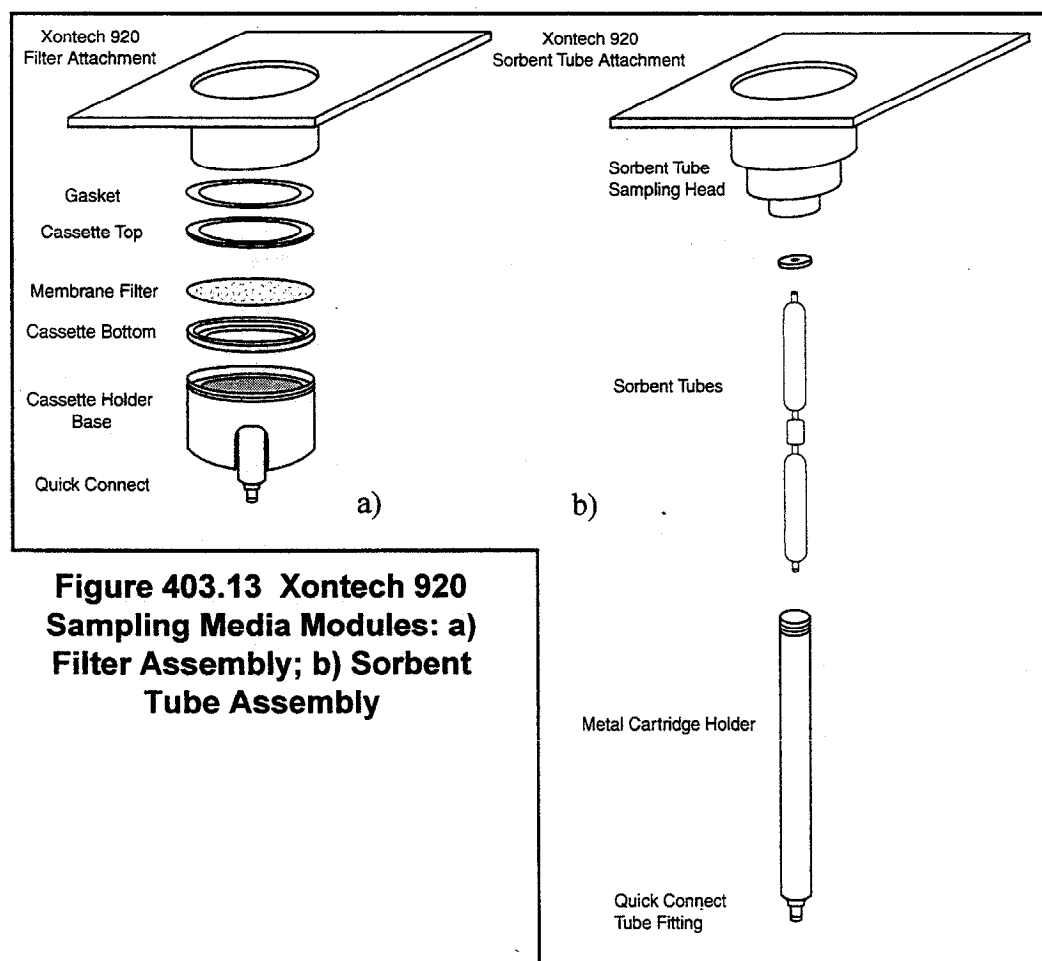


Figure 403.13 Xontech 920 Sampling Media Modules: a) Filter Assembly; b) Sorbent Tube Assembly

be collected on a filter. Some compounds, such as alcohols; however, are known to be "sticky" and cannot be quantitatively analyzed from canisters.

SUMMA canisters are coated inside with a polished layer of chrome-nickel oxide. The SUMMA coating is an inert material that will not react with most pollutants in the ambient air sample.

In addition to toxic air pollutants, the canister samplers are used to determine nonmethane organic compounds (NMOC). NMOC sampling is generally conducted over eight separate three hour periods. Canisters for NMOC analysis are collected through the XonTech 912 Multi-Channel Sampling Adapter which allows the attachment of several canisters and collecting sequential samples.

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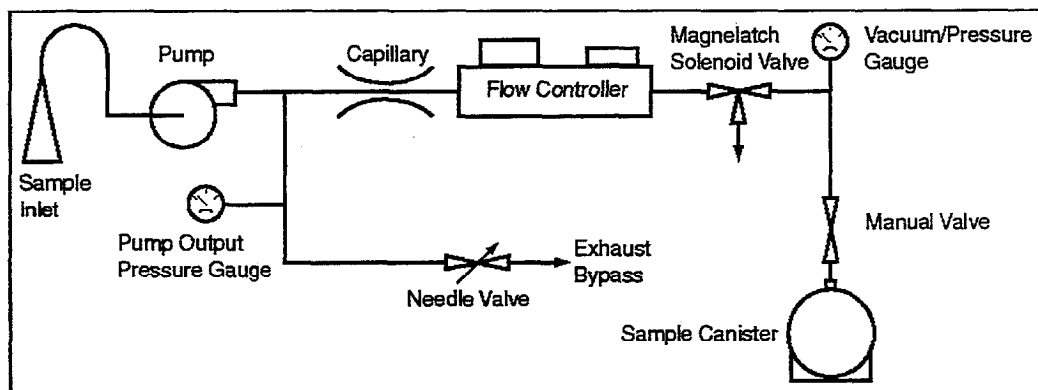


Figure 403.14 XonTech 910A Canister-Type Toxic Air Pollutant Sampler

Canisters are evacuated in the laboratory. If the vacuum of the canister at the beginning of sampling is not the same as when it was evacuated at the laboratory, a leak is indicated and the canister should not be used.

When setting up the sampler for a sample, an initial 30 minute purge is used to clear the sampler. Therefore, the timer should be set to begin operation 30 minutes before the solenoid opens to collect the sample. Collecting the sample is partly a matter of the initial vacuum of the canister drawing in the sample and partly a matter of pumping in more ambient air. The flow controller and capillary control the rate at which the sample is collected into the canister. Since the pump operates at a considerably higher flow rate than needed for sampling, the remainder is vented through the exhaust bypass. The pump draws approximately 1.5 to 3.5 liters per minute through the inlet, most of which is vented. This venting allows any variations in the pump operation to be eliminated through the vent. The pump provides approximately 20 psig back pressure. The final canister pressure should be 8.0 to 16.0 psig. After the canister has been returned to the laboratory, the pressure will be rechecked, if a leak is indicated by a change in pressure from the final value the sample will be voided.

The flow rate for the canister collection depends on the total length of time required for the sample. For a 24 hour sample the actual sample flow rate into the canister is approximately 7.6 cubic centimeters per minute (ccm) and for a three hour sample approximately 60 ccm.

Since the pollutant levels of the toxic air contaminants and NMOC are very low, care must be exercised to avoid contamination and leaks.

403.12 VISIBILITY

Visibility refers to the clarity with which distant objects can be seen. A more useful and specific term is "visual range" which expresses how far can be seen, i.e. the distance at which an object is barely discernible. Atmospheric visual range is governed primarily by the scattering and absorption of light by aerosol particles in the atmosphere. The scattering of light by air molecules usually has a minor effect, although it limits the maximum visual range to 100 - 300 km.⁶ The scattering coefficient is a parameter from the Beer-Lambert Law that defines the visual range; i.e. the maximum distance at which a dark object can be distinguished from a light background when viewed through the atmosphere. The extinction coefficient is an effective measure of optical properties. Koschmieder's law has been used to define the relationship of the extinction coefficient to visual range.

As progressively more distant objects are observed, each is lighter than the nearer ones. At the limit of visibility the objects become the same brightness as the horizon. What lightens the appearance and reduces the contrast relative to the sky is the light scattered to the observer by the intervening aerosol. As the distance is increased, more aerosol is between the observer and an object and the object appears lighter. Similarly, as the aerosol concentration increases, progressively nearer objects appear lighter and obscured.

The three primary means of monitoring visibility are the nephelometer, filter and tape samplers, and photographic monitoring. Each system monitors visibility by monitoring a different aspect of visibility.

403.12.1 Nephelometers

The integrating nephelometer is a photometer that is designed to measure the light scattered by particulate matter (b_{scat}) and gas molecules over as wide a range of angles as possible. The scattering coefficient is then used as a measure of the relative visibility. A typical nephelometer measures scattering over range from 7° to 170° and can measure scattering coefficients as small as 10^{-6}m^{-1} to 10^{-7}m^{-1} . A Nephelometer can be used to determine a point measurement of the scattering coefficient. Transmissometers and photographic monitoring can be used to measure open path optical properties.

Nephelometers can be used to estimate mass concentrations²⁴ with suitable calibration, but it is necessary to assume particle properties and that the size

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distribution remains constant. On average, the formula for relating the b_{scat} to the mass concentration of particulate matter is:

$$\text{mass } (\mu\text{g}/\text{m}^3) = 0.38 b_{\text{scat}}$$

Most nephelometers^{25,26} consist of two components: the optical assembly (the nephelometer itself, Figure 403.15) and a blower box. The blower box houses the sample blower, the clean air pump, and the power supply. The optical assembly contains the optical chamber, lamp assembly, and the electronic circuitry. The two parts are connected by an air sample hose, a clean air hose, and an electrical cable.

During operation, the ambient air sample is continuously drawn into the sensing volume of the optical chamber by the blower. The sample is then illuminated by the lamp. In some nephelometers the lamp is a quartz halogen lamp and provides continuous illumination. In other nephelometers the lamp is a strobe lamp and provides pulsed illumination. The sample is viewed by a photomultiplier tube through a series of apertures which define the sensing volume. Aerosol scattering is viewed against the dark background of a very efficient light trap. The light trap, apertures, and a highly efficient light-absorbing coating on all internal surfaces essentially eliminate scattering signals from the walls of the instrument. The geometry of the instrument provides an integrated value of the scattering coefficient over a relatively wide range of angles.

A filter in front of the photomultiplier tube limits the sensed light spectrum to that sensed by the human eye. The filter usually provides a narrow (approximately 40 nm) band of light in the green (approximately 540 nm) portion of the visual spectrum.

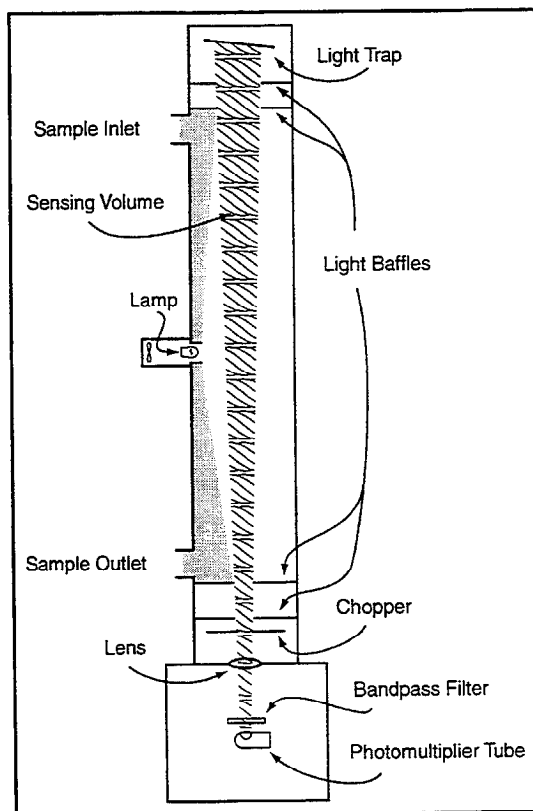


Figure 403.15 Schematic View of Nephelometer^{25,26}

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Ambient Air Monitoring

The use of a pulsed light source or a chopper in a continuous light source provides a dark signal to give a measurement of the photomultiplier tube dark current, which is subtracted from the measurement signal.

A third important signal is a measurement of the lamp intensity. This can be done with a photodiode to give a continuous lamp intensity measurement of a translucent portion of a shutter. The lamp signal allows the instrument to compensate for any fluctuations in the light source.

Periodically, the inlet flow is diverted through a high efficiency filter before entering the instrument. This provides a clear-air (zero) signal for the local environment. Filtered air also continuously bathes the light trap, photomultiplier tube housing, and the area between the lens and light baffles to keep these areas clean and limit the signal to the defined area in the sensing volume.

At high humidities, atmospheric particles such as sulfate and sea-salt adsorb water and can undergo a phase transition. The result is that the particles change size, shape, and refractive index. Operating the instrument in an air conditioned laboratory or monitoring station can result in sample flows with relative humidities exceeding 100% with resultant particle transitions and condensation on instrument walls. A heater protects against this problem by warming the walls of the chamber and inlet hose to match the temperature of the inlet air sample.

Since nephelometer data is only valid with RH above 95%, the measurement and recording of the relative humidity is very important for data validity. The inlets of the nephelometer are heated to prevent condensation in the instrument. The design of the Optec NGN-2 ambient nephelometer used by the IMPROVE monitoring network negates the problems with relative humidity and can measure the b_{scat} in conditions up to saturated fog.

Since generation of a known particulate sample for calibration and audits is a laboratory procedure ill suited for field work and the nephelometer responds to total scattering (including gaseous), calibrations and audits are conducted using gases with known scattering properties. In the past Freon-12 was typically used for this purpose, however, due to its stratospheric ozone depletion potential the use of Freon has been largely replaced with other gases. The most common calibration and audit gas is now SUVA®-134a (HFC-134a; 1,1,1,2-tetrafluoroethane). The calibrations and audits are two point checks: zero air and upscale using the SUVA span gas. The measurement points are then interpolated using the slope of the calibration line.

403.12.2 Filter and Tape Samplers

Filter and tape samplers measure the absorption (b_{abs}) of light by particulate matter. The total extinction of light in the atmosphere is the sum of the absorption and scattering (measured by nephelometers, see above). Operation of tape samplers was discussed in section 403.3.5, therefore this section will concentrate on filter samples for visibility sampling.

Optical absorption due to particulate matter (b_{ap}) is determined by evaluating the light absorption characteristics of fine particles collected on a filter.^{27,28} Fine particulate matter, around 1 μm , are primarily responsible for optical absorption. This determination adds an additional procedure to the laboratory work load, but has no impact on the work load of the field personnel.

The filter sample media is important if measuring b_{ap} in addition to particulate matter mass. A thin, very uniform filter, such as a stretched teflon filter, is required. The optical non-uniformity and thickness preclude the use of glass fiber filters. Samplers using this type of filter include the IMPROVE, dichot, and most of the new $PM_{2.5}$ samplers.

In the laboratory, in addition to pre- and post-weights of the filters, the optical properties of the filters is determined before and after sample collection. The b_{ap} can be measured by the laser integrating plate method and/or the laser integrating sphere method (LIPM and LISM respectively).

In the LIPM light from a diffused laser passes through the filter and is measured by a detector (Figure 403.16). The measurements of the light intensity transmitted through the filter before and after sampling is combined as:

$$b_{ap} = \frac{1}{L} \ln(I_0 / I)$$

where I_0 is the transmitted light intensity for the blank filter, I is the transmitted light intensity for the exposed filter, and L is the length of the air column sampled (L =sample volume / filter area). The detector output is calibrated against a series of standard filters daily.

The LIPM assumes that less than a monolayer of particles is present on the filter in order to avoid particles shadowing other particles. The magnitude of this 'loading correction' is dependent on the properties of the particular aerosol being

collected and can only be determined from empirical data. This problem can be minimized by keeping the filter loading light.

A second problem involves the question of light scattering within the filter and deposit. While the loading factor will bias the sample low, the internal scattering will cause an overestimate of the particle absorption. With the use of thin teflon filters the internal scattering is minimal.

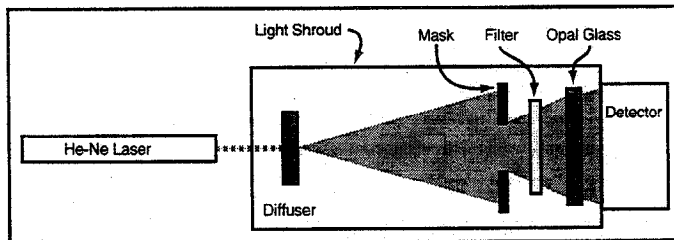


Figure 403.16 Laser Integrating Plate Method (LIPM)²⁸

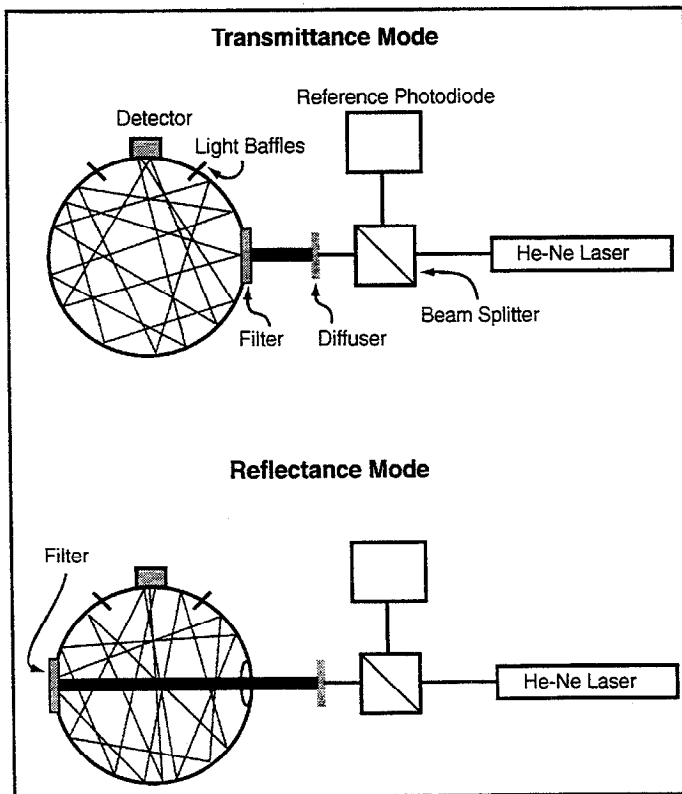


Figure 403.17 Laser Integrating Sphere Method (LISM)²⁸

An alternative to the LIPM is the integrating sphere method (LISM, Figure 403.17). The LISM analyzes both the transmittance and reflectance of the filters. The value $I_T / (1 - I_R)$, where I_T is the transmitted intensity and I_R is the reflected intensity, is equivalent to I / I_0 in the LIPM equation for b_{ap} . The two major advantages of LISM over LIPM for measuring b_{ap} are the reduced possibility of scattering losses between the filter and the detector and the ability to measure the back reflectance of the filter after sampling obviates the need for pre-exposure measurements on the blank filter.

403.12.3 Photographic Scene Monitoring

Scene monitoring (35 mm and digital still photography and time-lapse video) documents the visual appearance of hazes and the overall characteristics of the scene.²⁷ Scene monitoring is the only ground-based means of observing and characterizing elevated layers and plumes.

Scene documents the appearance of the scene of interest under a variety of air quality conditions and at different illumination conditions, at different times of day and different seasons. The primary objective of scene monitoring is to provide a qualitative representation of the scenic appearance of visual air quality. Measurements of visual range observations and target contrast have been interpreted as estimates of the light extinction coefficient (b_{ext}). However, these estimates have had limited usefulness due to uncertainties in the inherent contrast (which changes as a function of sun position) and cloud shading of the sight path, but not the target. These nonuniform lighting conditions can cause the extinction coefficient to be significantly underestimated e.g. the scattering coefficient is reduced when there is no sunlight on the particulate matter between the observer and the target to be scattered and create the intervening brightness.

The types of hazes documented by photographic means include:

- Haze (hazy) - A visual phenomenon resulting from scattering of light in a volume of aerosols. Condition of the atmosphere in which particles obscure a significant part of the vista.
- Uniform haze - Pollutants that are uniformly distributed both horizontally and vertically from the ground to a height well above the highest terrain.
- Layered haze - Haze that obscures a horizontal layer of a vista. Layered hazes can be ground-based (i.e. thin layer of haze at ground level) or elevated (i.e. a thin layer of haze above ground level).

The photographic record documents the appearance of the scene. The scenic characteristics include color, texture, contrast, clarity, and observer visual range. Photography is uniquely suited for identifying ground-based and elevated layers or plumes that may impact Class I or protected areas, as well as documenting conditions for interpreting aerosol and optical data from other monitoring procedures.

Photography of a plume emanating from a source and impacting a Class I area is sufficient to indicate impairment. A series of photographs can be evaluated to characterize the intensity, frequency, and duration of the visible plume. Sources, however, are frequently not visible from the Class I area, or their plumes disperse and are transformed into a uniform haze before reaching the area. In addition, visibility impacts are often the result of secondary aerosols formed from the conversion of gaseous emissions during transport of the pollutant containing air mass.

In a protocol for photographic scene monitoring photographs should be taken several times a day on a schedule tailored to capture periods when visibility impairment is most likely to occur at specified sites. To the extent possible, the selected scene should be collocated with or include aerosol and optical monitoring equipment to be able to correlate the three measures of visibility impairment. The combination of results can help establish cause and effect relationships.

Automatic still camera systems should meet the following requirements:

- A rugged, reliable 35 mm (equipped with an automatic film winder) or digital camera.
- An appropriate lens size to capture the entire scenic vista of interest (usually 135 mm or 50 mm)
- The camera should have a databack to imprint the date and time of the exposure on the film.
- The camera should have a programmable timer to trigger the camera at the selected times and days.
- Be able to operate in an ambient temperature range of -18° to $+49^{\circ}\text{C}$ (0° to 120°F).
- Be able to operate unattended for at least 10 days or a maximum of 30 days.

The site selected for photographic monitoring should view a recognizable, important vista that highlights the character of the area being monitored and represents regional (rather than local) air quality. Installation, servicing, aesthetics, and security should also be considered in site selection. To avoid lens flare, the view should be to the north or away from direct sun angles.

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A fine grain color slide film with good color reproduction, such as Kodachrome 64 in 36 exposure roll is the preferred media when 35 mm slides are taken. It is increasingly common for photographic scene monitoring to be conducted with digital cameras. Digital photography requires that a high resolution (megapixel or better) digital camera be used. The camera can be connected to the station computer and the photos taken on command from the computer. The digital images are then saved on the hard disk of the computer and can be downloaded to a central office for real-time analysis of visibility conditions.

The scene selected should include targets at varying distances from the observation (camera) position to be able to judge visual range, texture, contrast, color, and clarity of the scene. In addition, the resulting photographs should be analyzed for the presence and extent of uniform hazes, ground-based layered hazes, elevated layered hazes, and visible plumes from stationary sources. The photographs should be assigned numerical codes (for example, Table 403.1) that indicate the conditions at the time of the exposure. The codes should be marked directly on the slide frame and entered into a database or spreadsheet table. The codes and procedures should be tailored to the needs of the monitoring agency.

Time-Lapse Photographic Monitoring

Time-lapse photographic monitoring is a valuable technique for viewing and interpreting dynamic events.²⁷ Time-lapse imaging compresses the viewing time of long term dynamic events into time frames that give practical observations. Visualization of the encroachment of haze over a period of a few hours, with the advection of pollutants into a valley, or with the passage of weather fronts, etc. in conjunction with particulate, ozone, etc. monitoring (which provide more information about the cause of visibility degradation) illustrates the interpretive power of time-lapse monitoring. Reverse and stop frame functions during playback give further interpretive power to the method.

Time-lapse monitoring can be accomplished by 8 mm film or videotape. Videotape allows immediate viewing of the images and reproduction costs are minimal. For these reasons and since 8 mm film and cameras are rapidly becoming obsolete, videotape is almost universal for time-lapse monitoring. An additional future technology for video monitoring is the use of live-time internet web cameras.

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Table 403.1 Example Slide Condition Code Key²⁷

| Code | Sky Conditions | Code description |
|------|--|---|
| 0 | No clouds | No clouds visible anywhere in the sky. |
| 1 | Scattered clouds < half of sky | Less than one-half of the sky has clouds present. |
| 2 | Overcast > half of sky | More than one-half of the sky has clouds present . |
| 5 | Weather concealing scene | Clouds or precipitation are such that determination of the sky value is impossible. |
| 9 | No observation or cannot be determined | To be used with target code of 9 or if sky value cannot be determined due to reasons other than weather. |
| Code | Layered Haze | Code Description |
| 0 | No layer haze | No layered haze boundary (intensity of coloration edge) is perceptible. |
| 1 | Ground-based layered haze only | Only a single-layered haze boundary is perceptible with the haze layer extending to the surface. |
| 2 | Elevated layered haze only | An elevated layered haze with two boundaries is perceptible; e.g. horizontal plume. |
| 3 | Multiple haze layers | More than a single ground-based or elevated layered haze is perceptible. This can be multiple ground-based layers or a combination of both. |
| 5 | Weather concealing scene | Cloud or precipitation are such that determination of the presence of layered hazes is impossible. |
| 9 | No observation or cannot be determined | To be used with target code of 9 or if a layered haze value cannot be determined due to reasons other than weather. |

Siting for time-lapse monitoring is similar to that for still cameras, although temperature control, especially for the video recorder, is more stringent since these instruments are more sensitive to high and low temperatures.

Video time-lapse systems are easily programmed on-screen in a manner similar to used on a home VCR. The recorder can be programmed for record/playback speeds from real-time (2 hours per tape) to various time-lapse intervals up to 480 hours (20 days) per tape. At the appropriate interval, the tape in the recorder is replaced with a fresh tape and the recorded tape returned to the laboratory for analysis, reproduction, and archiving.

The videotapes should be reviewed to document dynamic occurrences of conditions similar to those identified from the still photographs, i.e.: weather conditions, uniform and layered hazes, emission sources, etc. The result of the quali-

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tative evaluation of the videotape is a file of codes. Final data summary tables and graphic plots can be made for reporting purposes. The videotape itself can be quite informative and instructive.

403.13 METEOROLOGICAL MONITORING

Meteorological monitoring, while not directly monitoring a pollutant, is important for a number of purposes: ^{29, 30}

- pollutant transport - Measurements of the wind speed and direction and atmospheric stability can tell the analyst the origin region and the history of the air mass containing the pollutants.
- atmospheric stability - When temperature readings are taken at two levels for a delta T, the atmospheric stability class can be determined.
- data validation and sample integrity - Monitoring data concerning some pollutant parameters, such as acid deposition and visibility are only valid under specific meteorological conditions.
- monitoring station siting (esp. PAMS and PSD) - PAMS and PSD monitoring programs require meteorological data to accompany the pollutant data.
- model data input and result validation - Meteorological data (stability and wind speed and direction) is an important input in pollutant dispersion models.
- secondary particulate matter formation - Secondary particulate matter forms during air mass transport and is enhanced by certain meteorological conditions.

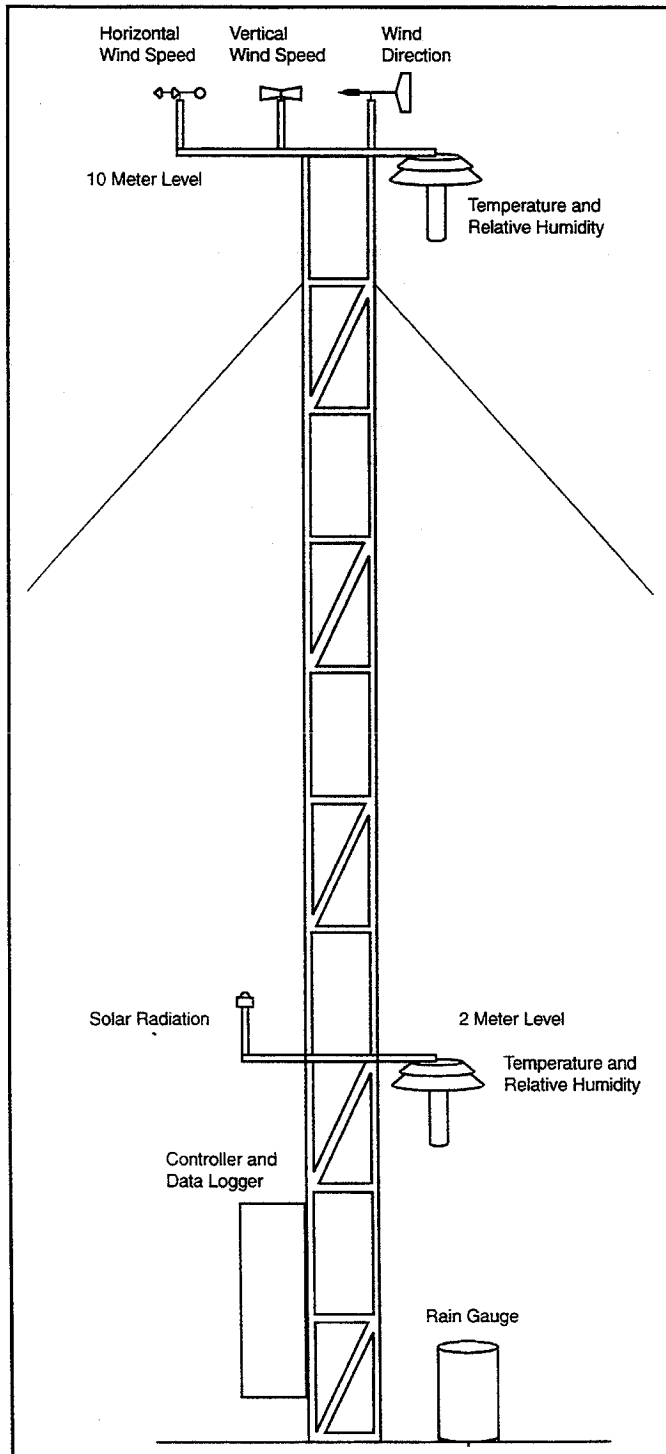
Meteorological measurements are usually made from a 10 meter tower (Figure 403.18) to avoid influences from the ground around the monitoring station and to measure the properties of the larger scale air mass.

The common meteorological parameters monitored include:

- Horizontal wind speed
- Vertical wind speed

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Ambient Air Monitoring



- Wind direction
- Temperature
- Relative humidity / Dew point
- Rain fall
- Barometric pressure
- Solar radiation

In addition, remote atmospheric monitoring is becoming more common as the technologies of such instruments as acoustic and radio-acoustic wind and temperature profilers is perfected. A phased array Doppler SODAR³⁰ measures wind speed and direction, vertical motions, turbulence, thermal structure, and mixing depth at various heights through the atmosphere.

Phased array sodar acoustic systems process the echo of an acoustic pulse which is directed into the atmosphere. The backscattered echo signal is due to thermal turbulence in the atmosphere. The frequency shift of the echo varies according to

Figure 403.18 Meteorological Monitoring Tower Configuration

the wind speed (the Doppler effect) while the intensity of the echo varies according to the thermal turbulence and structure of the atmosphere. Two acoustic beams are tilted 30° from vertical and turned 90° from each other to provide the horizontal component of wind velocity. A third beam is pointed vertically to provide the vertical component.

A radio acoustic sounding system (RASS) adds an electromagnetic aspect to the SODAR. A RASS processes a small part of the energy from a continuous radio wave backscattered by inhomogeneities in the atmosphere caused by an acoustic pulse emitted by the vertical antenna of the SODAR. Doppler processing of the signal received by a second radar antenna makes it possible to measure the speed of the vertically moving acoustic wave train and extract the air temperature.

403.13.1 Wind Instruments

All wind direction instruments must be placed so that they are not in the wake of other instruments or surrounding obstacles to smooth wind flow. Since wind speed and direction instruments are very sensitive to perturbations in the wind flow field and obstacles can effect a much larger area than is initially obvious, careful siting of the sensors is very important.³¹

The standard exposure of wind instruments over open level terrain is 10 meters above the ground, although the optimum measurement height may vary depending upon data needs. Open terrain is defined as an area where the horizontal distance between the instrument and any obstruction is at least ten times the height of the obstruction. If it is necessary to mount the wind instruments on the roof of a building (not a good practice, but sometimes necessary) they should be mounted high enough to be out of the area in which the air flow is disturbed by the building (Figure 403.19; also, for more information see Section 604.4 of this manual). This is usually about 1.5 times the height of the building above the roof so that it is out of the wake.

Aside from having the instruments properly exposed, they must also be vertically true. If a cup anemometer is not properly balanced deviations from vertical have particularly important effects; especially in that the starting threshold will be degraded. Wind direction indicators, especially when not properly balanced, will also have their starting threshold degraded and the predominant wind direction for light winds may be significantly biased if they are not properly aligned in the vertical direction. Wind vanes will also be significantly influenced by the tower on which they are supported. Unless the wind vane is on the

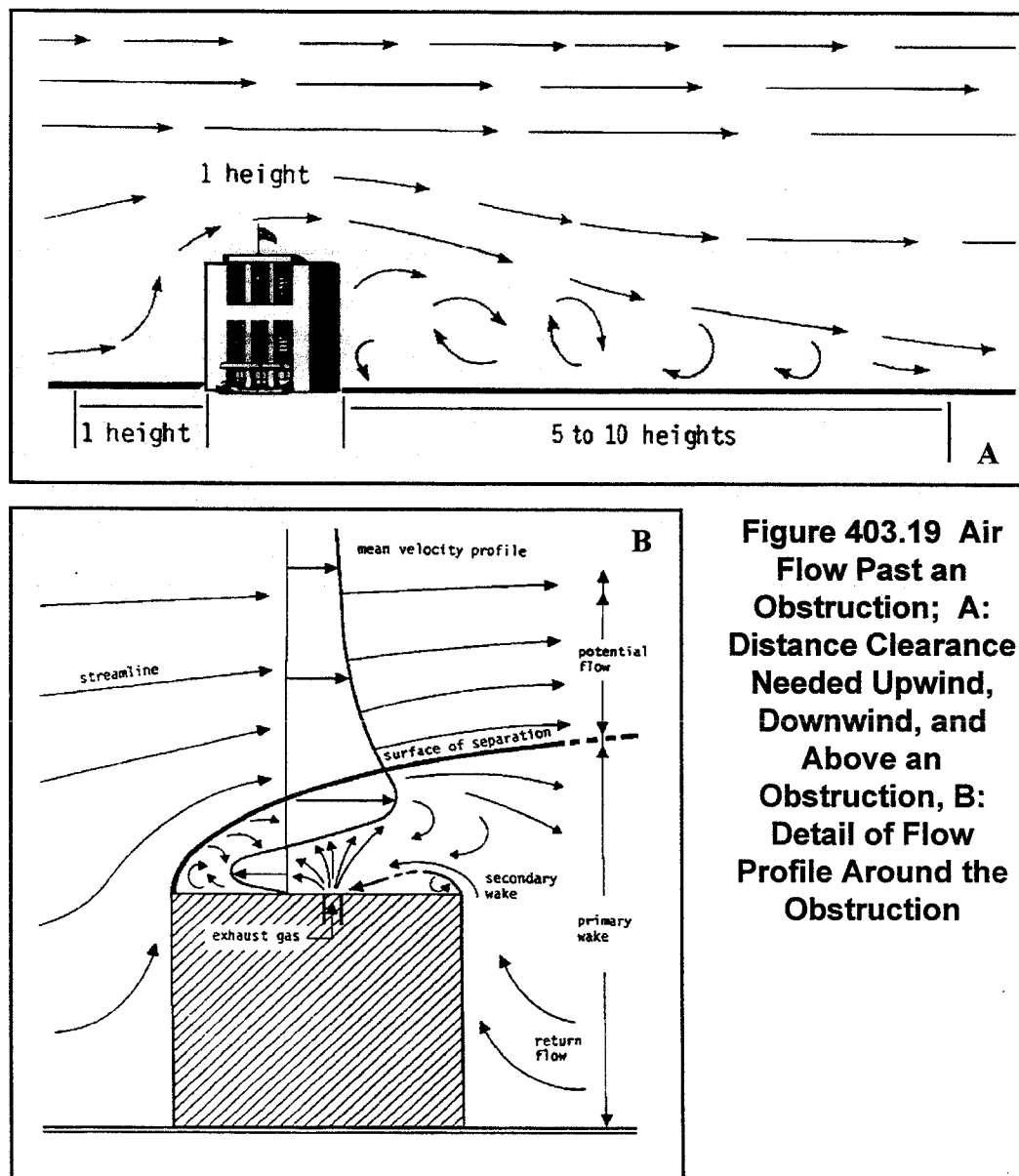


Figure 403.19 Air Flow Past an Obstruction; A: Distance Clearance Needed Upwind, Downwind, and Above an Obstruction, B: Detail of Flow Profile Around the Obstruction

top of the tower there will be an interference sector where the wind must go through the tower structure before it gets to the vane. If the instruments cannot be mounted at the top of the tower, they should be mounted on a boom at a distance at least twice the maximum diameter or diagonal of the tower away from the nearest point of the tower. The boom should project into the direction which provides the least distortion for the most important wind direction. For example, a boom mounted on the east of a tower will provide the least distortion for north or south winds.

Horizontal Wind Speed

Most commonly, horizontal wind speed is measured by three cup³² (Figure 403.20) or propeller-type anemometers. There are; however, other measurement means; such as ultrasonic and sonic anemometers.

Ultrasonic and sonic anemometers^{33, 34} (Figure 403.21) have the advantages that they can measure wind direction at the same time as the wind speed and they have no moving parts. A sonic anemometer measures the wind velocities in one, two, or three axes. Piezoelectric crystals transmit sonic signals along the fixed orthogonal directions. Microcomputer electronics then process the data to calculate the wind velocity in each axis giving both a resultant wind direction and speed.

No matter which type of anemometer is used, it is important that the instrument is vertically and horizontally true and level.

The cup and propeller anemometers measure the wind speed by measuring rotational speed. This depends on low shaft turning resistance and low starting torque. The starting torque must be low enough to give a starting threshold speed of less than 0.5 m/s (~1 mile per hour).

Different models of anemometers determine the rotational speed in different manners. Generally, instruments use physical, electrical, or optical methods to generate a frequency signal related to the rotation. One method is to use a chopper to modulate an optical signal. Another method is to produce an alternating current sine wave signal with a frequency proportional to the wind speed.

During calibrations and audits the correlation of the rotation speed to the reported wind speed is checked by spinning the shaft at a known rate and reading the final readout of the instrument. The starting torque is also checked during

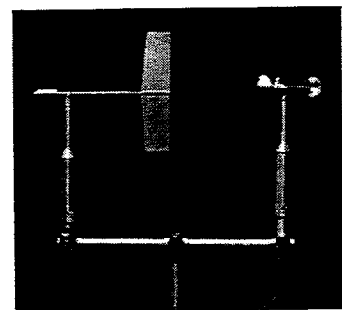


Figure 403.20 Wind Speed and Direction Instruments (MetOne)

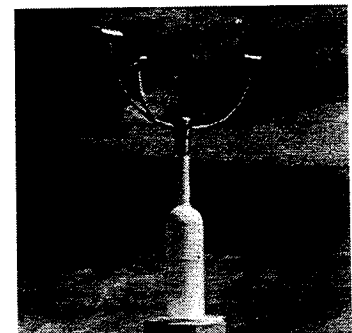


Figure 403.21 Sonic Anemometer (MetOne)

calibrations and audits by attaching weights to a torque disk until it freely rotates.

Vertical Wind Speed

Vertical wind speed monitors are usually high efficiency propeller-type instruments. These instruments are similar to the propeller-type horizontal wind speed instruments, but oriented on the vertical axis. However, it is especially important that the propeller turns with very little torque since vertical wind speeds are never very great. The starting torque should be checked during audits and calibrations.

Wind Direction

Wind direction sensors provide information about the azimuth angle from which the wind is blowing. In most cases, the wind direction is determined by a wind vane (Figure 403.20). Ultrasonic anemometers can give wind direction in addition to the wind speed with no moving parts; however, they are rarely used in the field.

A wind vane³⁵ consists of a tail assembly which is positioned on a vertical shaft. When the wind blows it applies a force to turn the tail to the point of minimum and balanced forces, i.e. it turns so the tail is downwind in the wind direction. The shaft is supported by low friction precision bearing and is connected to a low torque potentiometer. The potentiometer will yield a voltage output proportional to the wind direction.

The proper orientation of the sensor to true north, efficient operation of the bearing assembly, and correct potentiometer function are factors which can effect the quality of the wind direction data. Periodic calibration (every six months), audits, and maintenance helps assure that the sensor functions correctly. The sensor index should be oriented with respect to true north. When setting-up the station or servicing the sensor, a compass, adjusted for the proper site declination, should be used to install the sensor accurately within two degrees of true north. As with the vertical wind sensor, the starting torque should be checked during audits and calibrations.

403.13.2 Temperature, Relative Humidity, and Dew Point

Temperature and humidity instruments are sensitive to the type of surface over which they are mounted. They should be mounted over a plot of open level ground at least nine meters in diameter. The ground surface should be non-irrigated or unwatered short grass or natural earth. The surface must not be concrete or asphalt or oil soaked. Areas of standing water should also be avoided. The sensors should be at least 30 meters from large paved areas. The surface should be level, avoiding steep slopes, ridges, and hollows. The standard height for climatological purposes is 1.25 to 2 meters, but different heights may be required for air quality purposes.

Sonic anemometers (see section 403.13.1), in addition to providing wind speed and direction information also provide a measure of the temperature. The sonic temperature is similar to virtual temperature. It will differ from the absolute temperature by an amount proportional to the water vapor content of the measured air.

More common than sonic measurements are thermistor measurements of temperature.³⁶ Wire bobbins and thermocouples may also be used for temperature measurements. Standard mercury-in-glass thermometers are not transducers (i.e. not part of an electronic circuit that records the temperature) and so are not used as temperature sensors; although they may be used as audit and calibration devices.

Thermistors are electronic semiconductors made from oxides of metals such as nickel, manganese, iron, cobalt, magnesium, titanium, etc. Most thermistors are nonlinear, requiring that they be incorporated into linearizing networks or linearized in the data processing stage of data collection. Several manufacturers make platinum RTDs (resistance temperature detector) that yield linear data. However, they generally give much smaller signals than the more conventional sensors (0.4 to 4 ohms per degree with the RTD vs 100 to 800 ohms per degree for the nonlinear devices).

The big advantage of thermistors is the relatively large resistance of the element with respect to the resistance of the signal cable (i.e. the resistance measured is

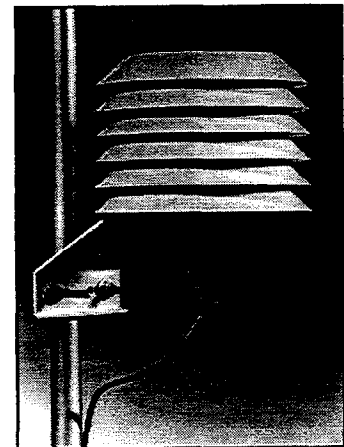


Figure 403.22
Temperature and
Relative Humidity
System (MetOne)

primarily due to the element and not to the cable). The output of thermistors is also quite stable.

Wire bobbins are related to thermistors. The resistance of almost any wire changes with temperature; however, that change is small per unit length. By winding a long length of wire on a spool, it can be used as a temperature sensing element. If the spool is large and open a fast response element can be made.

Different metals have different resistances (Table 403.2). Manufacturers select the wire composition based on the stability of the sensor, ease of handling, and cost. Platinum is the most common for meteorological purposes. Nickel-iron is another common wire used.

Thermocouples operate on the principle that when two different metals are joined a temperature dependent voltage is generated. By comparing the voltage generated by a junction in the ambient atmosphere with the voltage generated by a junction at a controlled temperature the temperature of the first (ambient) junction can be determined.

Thermocouples are infrequently used for ambient monitoring because of the complex circuitry and problems with the conductors. They are useful; however, for differential temperature measurements. They also are useful for miniature fast response devices.

To obtain good quality temperature data it is important that the sensor be shaded from direct sunlight. Various kinds of shields, both naturally and mechanically aspirated, have been used. The temperature and relative humidity sensors in Figure 403.18 incorporate a common shield design. In a mechanically aspirated shield a fan draws air into the sensor chamber at a rate that will minimize error.

Measurements of the moisture in the air are closely related to the ambient temperature measurements. Moisture in the air can be expressed in a number of ways: dew point temperature, relative humidity, absolute humidity, specific humidity, and mixing ratio. Dew point temperature and relative humidity are the two most commonly used terms. The dew point temperature is the temperature to which air must be cooled, at constant pressure and water vapor content, to

Table 403.2 Wire Resistances (Ohms per meter at 20EC, 40 Gauge [0.08 mm])

| Element | Resistance (Ω/m) |
|----------|----------------------------------|
| Copper | 3.4 |
| Silver | 65.9 |
| Platinum | 20.0 |
| Iron | 20.0 |
| Nickel | 15.6 |

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be saturated with respect to liquid water. Relative humidity is a dimensionless ratio of the actual vapor pressure of the air to the saturation vapor pressure at a given dry bulb temperature.

There are many ways of measuring the water vapor content of the atmosphere. These can be classified in terms of six physical principles (Table 403.3).

More measurements of atmospheric water vapor content have probably been made with a psychrometer than by any other manual method. Psychrometry uses the latent energy of the evaporation of water to give a wet bulb temperature depression (i.e. evaporative cooling that takes place at the existing ambient temperature, water vapor partial pressure, and atmospheric pressure). Use of the wet bulb temperature and the dry bulb temperature with a psychrometric chart or calculation can give the relative humidity and dew point. The psychrometric method presents servicing problems when applied in a monitoring system. However, it is convenient for audits of other devices.

Table 403.3 Principles of Humidity Measurement

| Principle | Instrument / Method |
|---|---|
| Reduction of temperature by evaporation | Psychrometer |
| Dimensional changes due to absorption of moisture, based on hygroscopic properties of materials | Hygrometers with sensors of hair, wood, natural fibers, and synthetic fibers |
| Chemical or electrical changes due to absorption or adsorption | Electric hygrometers such as Dunsmore Cell; lithium, carbon, and aluminum oxide strips; capacitance films |
| Formation of dew or frost by artificial cooling | Cooled mirror surfaces |
| Diffusion of moisture through porous membranes | Diffusion hygrometers |
| Absorption spectra of water vapor | Infrared and UV absorption; Lyman-alpha radiation hygrometers |

Many instruments operate on hygroscopic characteristics of materials. In one subset of these instruments, the materials (such as human hair and other fibers) change their physical dimensions such as lengthening or shortening when absorbing or desorbing moisture.

Another subset that can provide direct electronic data are the electronic hygrometers. These devices use hygroscopic changes in electronic characteristics to generate a water vapor content signal. A thin film capacitor is a commonly used

humidity sensor that contains a polymer dielectric about 1 micrometer thick. The sensor capacitance is dependent on the water absorption in the sensor's dielectric material. That capacitance value can be recorded and used to calculate the relative humidity. The sensor is small (4 X 4 X 0.2 mm), hence its thermal mass is also small and the sensor can very closely and quickly follow the ambient air temperature.

Chilled mirror surfaces have also been used for dew point and relative humidity measurement by cooling a mirror to the point where the reflection of a light shining on the mirror changes because of the condensation or freezing of water on the mirror surface. This process is a fundamental measurement and therefore does not require calibration aside from periodically heating the mirror to zero the optical system to correct for dry mirror reflectance changes due to contamination. The temperature measurement portion of the system does, however, require periodic calibration.

The following equation will calculate the relative humidity ($RH = 100 \times r$; in percent) from the ambient air temperature (T , °C) and the dew point temperature (T_D , °C):

$$r = \exp \left\{ a \left[\left(\frac{T_D}{b + T_D} \right) - \left(\frac{T}{b + T} \right) \right] \right\}$$

where $a = 17.27$ and $b = 237.3$

The following equation will calculate the dew point temperature from the ambient temperature and relative humidity:

$$T_D = \frac{b \left[\ln r + \frac{aT}{b + T} \right]}{a - \left[\ln r + \frac{aT}{b + T} \right]}$$

To calculate the relative humidity from the ambient air temperature, wet bulb temperature (T_w , °C), and atmospheric pressure (P , mb) through the vapor pressure (e , mb) and saturation vapor pressure e_s , mb) use the following equation:

$$r = \frac{e}{e_s} = \frac{e_{sw} - A P (a + B T_w) (T - T_w)}{e_o \exp \left[\frac{aT}{b + T} \right]}$$

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where $A = 6.6 \times 10^{-4}$ and $B = 1.15 \times 10^{-3}$ and:

$$e_{sw} = e_o \exp \left[\frac{aT_w}{b + T_w} \right]$$

403.13.3 Barometric Pressure

Atmospheric pressure is not generally a required parameter to measure for air pollutant monitoring. A pressure value may be required for the calibration or data interpretation; for example, the above formulas for converting wet- and dry-bulb temperatures to dew point temperatures or relative humidity.

In most cases, a standard atmospheric pressure for the station elevation will give good enough pressure values. A value of $\pm 1\%$ (equivalent to ± 10 hPa or 100 meters in elevation) is generally within the accuracy needs of the station data stream. For greater accuracy (especially for calibrations and audits) without measurement, the current (uncorrected) station pressure from a local airport will provide the adjustment of the standard atmospheric pressure to actual conditions.

Audits and calibrations of field instruments use certified laboratory calibrated portable transfer standard instruments.

When actual measurements are desired, the two most common barometers are the aneroid barometer and the mercurial barometer. Most electronic barometric pressure systems use an aneroid pressure transducer. The motion of the sensor as a result of pressure changes may be detected by a number of methods. The most common and most accurate is the capacitor type.

If maximum accuracy is important, care must be given to the exposure of the pressure sensor. The sensor is sensitive to both the atmospheric pressure (weight of the atmosphere above the instrument) and wind pressure. Therefore, the sensor must be shielded from wind effects which may take the form of direct pressure of the blowing wind on the sensor or pressure and vacuum effects on the upwind and downwind sides of obstacles as the wind swirls around the object.

Meteorologists commonly use units of millibars for barometric pressure. In SI units, the standard unit is the Pascal (Pa). In SI units the barometric pressure is often expressed in hecto Pascal (hPa; i.e. 100xPa) since the value in hPa is

equivalent to the value in mb (1 atm = 1013.25 hPa or 1013.25 mb). Other units include: 29.9213 in Hg, 760 mm Hg, and 14.6959 lb/in².

403.13.4 Rain Fall

A rain gauge collects representative samples of rainfall. Some ambient monitoring parameters, such as acid rain, require that rainfall be monitored.

At the outset, it should be recognized that rainfall may be patchy and the assumption that the rainfall measured at a monitoring station can be readily extrapolated to precipitation amounts for a larger region may be questionable. A network of stations is preferable and proper siting of the stations is very important.

At its simplest, a rain gauge is an open-top can with vertical sides into which precipitation will fall. The amount (i.e depth) of precipitation can then be measured with a ruler. In ambient monitoring automated systems are much more useful since they will give the start and end times of the precipitation event, the rate of precipitation, and evaporation and run-off are prevented and do it without an onsite operator. Most rain gauges incorporate a funnel rather than simple straight sides to increase the sensitivity of the readings.

Recording rain gauges came in two basic designs: weighing-type and the tipping bucket type. The weighing-type rain gauge is also known as the universal-type since it can measure the both liquid and frozen precipitation. A weighing gage rotating drum chart recorder to produce a record of the precipitation events. As the weight of precipitation increases, the pen on the chart moves from the base of the drum to the top.

The tipping bucket type rain gauge is designed with a funnel that directs the precipitation into a small outlet directly over two equal compartments (i.e. buckets) which tilt in sequence. Each bucket as it tips measures 0.01 inches of precipitation. The motion of the buckets momentarily closes the contacts of a mercury switch providing digital-type impulses each equal to 0.01 inches of precipitation. When the rate of rainfall is high the tipping bucket rain gauge can under measure the rainfall amount due to spillage and unmeasured precipitation while the tipping bucket switches from one position to the other.

A rain gauge should be mounted on level ground do the collection opening is horizontal. The gauge should be shielded from the wind, but it must not be

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placed is an area where there will be excessive turbulence caused by the shield. Obstructions to the wind should not be closer than two to four times the obstruction height from the instrument. Wind shields represent an essential accessory, especially snow in windy conditions. The improved Alter design, made of 32 free swinging leaves supported 1/2 inch above the level of the collecting opening is an effective way to improve the precipitation catch. In a comparison of shielded vs. unshielded 8 inch rain gauges, it has been shown that at a wind speed of 5 mph the efficiency of the unshielded gauge decreases by 25% and at 10 mph the efficiency decreases by 40%.

The ground surface around the rain gauge should be natural vegetation or gravel. The surface should not be paved to prevent splashing into the gauge. The gauge should be mounted at least 30 cm above the ground and should be high enough that it will not be covered with snow in the winter.

In below freezing conditions when the catch is largely snow, it is necessary to remove the funnel in weighing gauges. Some instruments are equipped with heaters to melt any frozen precipitation. Caution should be exercised in heating a rain gauge so as to prevent evaporative losses.

403.13.5 Solar Radiation

Solar radiation is the driving force of atmospheric circulation and much of the atmospheric chemistry. In addition, although air pollution investigators normally consider solar radiation measurements secondary to wind and temperature measurements, it is directly related to atmospheric stability.

Solar radiation is measured³⁷ as incoming-, outgoing-, or net radiation. Quantitatively, solar radiation is described in units of energy flux, i.e. W/m^2 or $\text{cal/cm}^2/\text{min}$. Solar radiation can be measured as broadband solar radiation or in narrow, specific wavelength bands to evaluate air pollution parameters such as atmospheric turbidity, precipitable water, and rates of photochemical reactions.

The most common type of solar radiation monitoring devices is the pyranometer. Pyranometers have a hemispherical optical glass window (the type of glass and its properties in the specific wavelengths measured is important) which measures the radiation from the whole sky. The window may be a transparent dome that can be exchanged for a filter dome to give narrow, specific wavelength measurements or a flat-face window (Figure 403.23).

In most models the sensor consists of a differential thermopile. The typical detector element is a wirewound-plated construction with black and white segments. When exposed to solar radiation, the differing absorptivity of the black and white segments develops a temperature differential. The thermopile then produces a voltage proportional to the solar radiation. Some pyranometers may use a silicon photovoltaic cell as a detector or consist of a flat-faced silicon photodiode.

An additional sensor type, useful in areas without electrical power, is the bimetallic recording sensor. These mechanical sensors consist of two or three bimetallic strips, alternately painted black and white, that respectively absorb and reflect solar radiation. The resulting differential heating produces a deformation that is transmitted mechanically through levers and to the pen arm of a clock-wound drum recorder.

The site selected for an upward-looking pyranometer should be free from any obstruction above the plane of the sensor and should be readily accessible for cleaning and maintenance. It should be located so that no shadows are cast on the instrument. Nor should the instrument be located so that sunlight is reflected into the sensor from brightly colored walls or other surfaces. Usually a tall platform or roof of a building is the most suitable location.

403.14 CALIBRATORS AND ZERO AIR SUPPLIES

Calibrators and zero air supplies at the ambient air monitoring station are oriented toward routine zero and span checks. These "unofficial" (level 2) zero and span checks of the analyzer's response may include dynamic checks with uncertified gases, artificial stimulation of the analyzer's detector, electronic or other checks of a portion of the analyzer, etc. The level 2 zero and span checks are intended as quick, convenient checks to be used between calibrations to check for possible analyzer malfunctions or calibration drift. Whenever a calibration problem is detected, a level 1 calibration or audit should be conducted before any corrective action is taken. The "official" calibrations and audits must be conducted with external devices and by persons not directly associated with the station.

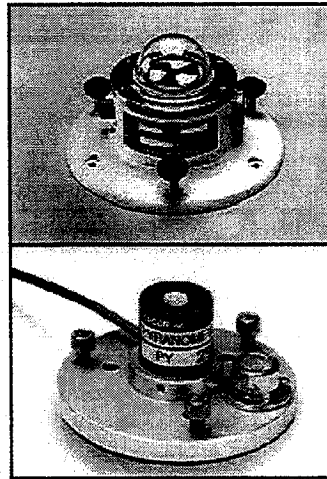


Figure 403.23
Domed and Flat-Face
Pyranometers

If a level 2 zero and span check is to be used in the quality control program, a reference response must be obtained immediately following a level 1 zero and span calibration while the accuracy of the analyzer's calibration is known. Subsequent level 2 checks should then be compared to the most recent reference response to determine if response changes have occurred. Any response check that involves only a portion of the analysis system cannot be used as a verification of the overall analyzer calibration.

403.14.1 Zero Air Supplies

Zero air (i.e. air containing no pollutants) can be supplied from a compressed gas cylinder or a pure air generator. Compressed gas cylinders are externally certified and provide a higher level of quality control. However, since zero air may be extensively used throughout the monitoring station, the cylinders may be expended rapidly. Therefore, pure air generators are usually used. The output of the pure air generator must be checked against a certified pure air cylinder, but the uses in the monitoring station that demand significant quantities of pure air draw from the pure air generator.

Pure air generators remove pollutants present in the air such as hydrocarbons, methane, CO, sulfur oxides, and nitrogen substances. The units are typically³⁸ composed of an air compressor, pollutant adsorber, hydrocarbon reactor, and cooling coil. The air compressor provides ambient air to the pollutant adsorber and hydrocarbon reactor which remove pollutants from the air. A cooling coil is needed because the hydrocarbon reactor heats the air to over 300°C. The output is a constant supply of zero air at up to 30 liters per minute (LPM).

Filters, similar to chromatographic columns, during the pollutant adsorbing phase adsorb the pollutant gases, allowing a storage of pure gas in a small reservoir. Then, with a part of the purified gas, a regeneration phase (flow in opposite direction-backflush) desorbs the collected pollutants and discharges them outside.

Hydrocarbons are removed through oxidizing action carried out by the platinum and palladium catalytic reactor which is kept at a temperature of 370°C. Any hydrogen, carbon monoxide, carbon dioxide, and humidity produced is also destroyed through this process.

The activated carbon filter located in series to the reactor, absorbs sulfur and nitrogen products, H₂O and O₃.

In addition to the catalytic reactor and the filter, the TOC purifier is also equipped with a special molecular sieve dryer able to remove water (to a dew point temperature of -70°C) and CO_2 (to < 1 ppm). These operations, effected in cycles, allow continuous production of high purity air (99.9995%).

The hydrocarbon reactor is hot while operating; therefore, care is needed when working around it to prevent burns. Also, the ballast tank contains compressed air; as with any pressurized tank, the pressure must be bled off before working around it.

403.14.2 Calibrators

Calibrators are designed to produce very precise and accurate concentrations of pollutants for calibrating and auditing air monitoring instruments. They contain mass flow controllers and precision circuitry to deliver the exact amount of the selected gas flows. They also usually contain an ozone generator module.

Most calibrators mix air from the zero air system (Section 403.14.1, above) with concentrated pollutant gases from certified gas cylinders. Some calibration systems use permeation tubes instead of gas cylinders. Permeation tubes work by having a very highly concentrated pollutant (often in a pure liquid form) in a permeable tube which allows a constant rate of pollutant to permeate out of the tube. A carrier gas flowing through the permeation tube holder will then contain a known, constant pollutant concentration. Since the permeation tube output is proportional to temperature, it is important to maintain the temperature to $\pm 0.1^{\circ}\text{C}$. It is also important to precisely control the carrier gas flow rate.

Ozone is photometrically produced when a dry air stream is irradiated by a UV source with a wavelength ≤ 210 nm. A low pressure, cold cathode, mercury plasma discharge lamp can provide a stable radiation source for ozone generation. To ensure a constant, repeatable ozone concentration the generator chamber must be kept at constant temperature (approximately 50°C) and a constant air flow maintained through the chamber.

In operation, a calibrator adjusts the mass flow controllers (either manually or automatically) to provide concentrated pollutant gas and pure air in the correct proportion to achieve the desired calibration or audit concentration. Due to instability during storage, gas cylinders contain NO rather than NO_2 . To calibrate or audit the NO_2 function of a NO_x monitor NO is reacted with ozone to produce NO_2 . A small amount of NO should remain in the gas stream. This is

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discussed in more detail in the NO_x monitor section of this manual (Section 403.6).

403.15 DATA ACQUISITION SYSTEMS

All data collected by ambient air monitoring eventually will be stored in electronic files such as AIRS. The data can either be recorded from the monitoring station onto data forms and then input into the final files or directly uplinked through computer systems. Often the most significant source of errors in the data acquisition process is in reading charts and recording the data. The most common errors are the transposition of digits and incorrect placement of the decimal point. Systems which automate those functions typically are more error free. Computerized systems also reduce personnel time in reading charts and recording data. All data should be reviewed for completeness and accuracy regardless of how it is entered into the final files.

The data acquisition system incorporates the equipment and techniques for gathering, storing, and doing basic manipulation of the data. These processes may be manual recording, calculating, and data entry; completely automated and computerized systems; or systems with intermediate levels of automation.

Strip chart recorders are one of the most reliable and permanent data recording (logging) instruments. Since they are paper records, they are not subject to changes in computer technology making the files obsolete or the loss of computer files. However, strip chart recorders are subject to mechanical failures and the data must be hand read and recorded.

Since strip charts present a graphical view of the data they are well suited for rapid scanning by the station operator for the occurrence of zero/span calibration checks, periods of pollutant concentration exceedance, and certain types of system errors. For this reason they are often emulated on computerized systems.

Some of the errors that the station operator should check for on strip chart (or computer emulation) traces include:

- A straight trace for several hours
- Excessive noise as indicated by a wide solid trace or erratic behavior such as spikes that are sharper than possible given the normal response time of the

instrument (noisy outputs may be the result of analyzers exposed to vibration or unbalanced electrical components).

- A long steady increase or decrease in deflection.
- A cyclic pattern of the trace with a definite time period indicating a sensitivity to changes in temperature, atmospheric pressure, or parameters other than the pollutant concentration.
- Periods where the trace drops below the zero baseline (this may result from a larger than normal drop in the ambient room temperature or power line voltage).

Data for any time period for which these indicators exist should be voided and the cause examined and corrected.

Very rarely is a strip chart recorder the sole data acquisition device; although most stations continue to have strip chart recorders. For the most part, data loggers with telemetry and/or computer control and data acquisition have replaced strip charts as the primary data acquisition means.

In automated data acquisition systems the data acquisition equipment (either data logger or computer) polls each instrument at the station on a routine basis. The raw data is stored and used, along with calibration factors and averaging factors, to calculate the reporting values (i.e. hourly, eight hourly, and daily averages; peak concentrations; etc.).

A key point of inspection is to check the factors used in the data acquisition system. The data acquisition system is also a key point in the data handling (Section 700), documentation (Section 800), and quality assurance (Section 900) evaluation of the ambient air monitoring station.

404 REFERENCES

1. U.S.EPA, 1994, *Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II: Ambient Air Specific Methods*, EPA/600/R-94/038b.
2. California Air Resources Board, 1978 (Revised 1997), *Air Monitoring Quality Assurance Volume II: Standard Operating Procedures for Air Quality Monitoring*.

400 INSTRUMENTATION

3. Minnich, Timothy R., Robert L. Scotto, Robert H. Kagann, and Orman A. Simpson, 1990, Air Monitoring, *Hazmat World*.
4. American Conference of Governmental Industrial Hygienists, 1988, *Advances in Air Sampling*, Lewis Publishers.
5. U.S.EPA, 1992, *Continuous Emissions Monitoring Systems, Student Manual for APTI Course 474*.
6. Hinds, William C, 1982, *Aerosol Technology*, John Wiley & Sons.
7. Jahnke, James A, 1993, *Continuous Emission Monitoring*, Van Nostrand Reinhold Co, New York.
8. Air and Waste Management Association, 1993, *Continuous Emission Monitoring: A Technology for the 90's*.
9. Nicolet Instrument Co, Technical Notes: *Measuring the Signal-to-Noise Ratio of an Infrared Spectrometer*.
10. Dasibi Instrument Corporation, (undated), *Dasibi Model 3008 Carbon Monoxide Analyzer Instrument Manual*.
11. Instrumental Methods of Chemical Analysis.
12. Lodge, James, P. (Editor), 1989, *Methods of Air Sampling, Third Edition*, Lewis Publishers, Inc, Chelsea MI.
13. Willard, Hobart H., Lynne L Merritt Jr., and John A. Dean, 1965, *Instrumental Methods of Analysis*, Van Nostrand Reinhold Co, New York.
14. Meyer, Michael B., 1993, Applications of Continuous PM₁₀ Measurements, Presented at The Role of Meteorology in Managing the Environment of the 90's, Scottsdale, Arizona, 16-28 January 1993.
15. Patashnick, Harvey and Erich G. Rupprecht, 1991, Continuous PM₁₀ Measurements Using the Tapered Element Oscillating Microbalance, *J. Air & Waste Manage Assoc*, 41:1079-1083.

400 INSTRUMENTATION

Ambient Air Monitoring

16. U.S.EPA, 1999, *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air - Second Edition*, EPA/625/R-96/010b.
17. *Code of Federal Regulations, Title 40, Part 50*, 1998, U.S. Government Printing Office.
18. Subramanian, K.S., C.L. Chakrabarti, J.E. Sueiras, and I.S. Maines, 1978, Preservation of Some Trace Metals in Samples of Natural Waters, *Analytical Chemistry*, 50:444-448.
19. *Code of Federal Regulations, Title 40, Part 53*, 1998, U.S. Government Printing Office.
20. *Code of Federal Regulations, Title 40, Part 58*, 1998, U.S. Government Printing Office.
21. Van Vaeck, L., K. Van Cauwenberghe, and J. Janssens, 1984, The Gas-Particle Distribution of Organic Aerosol Constituents: Measurement of the Volatilization Artifact in Hi-Vol Cascade Impactor Sampling, *Atmos. Environ.*, 18:417.
22. Cadel, S.H., 1983, Problems in the Sampling and Analysis of Carbon Particulate, 17:593.
23. Environment U.S.A., Product Information: Ambient Suspended Particulates Monitor - Model MP101M.
24. Brauer, Michael, Andrea 'tMannetje, and Barbara Lang, 1996, Continuous Assessment of Indoor Fine Particles with a Portable Nephelometer, *Proceedings of the Second Colloquium of Particulate Air Pollution and Health*, Park City, Utah, 1-3 May 1996.
25. TSI Incorporated, 1999, Product Information: Model 3551 Integrating Nephelometer.
26. Belfort Instruments Incorporated, 1999, Product Information: Model 1590 Integrating Nephelometer.
27. U.S.EPA, 1999, *Visibility Monitoring Guidance*, EPA-454/R-99-003.

400 INSTRUMENTATION

28. Campbell, Dave, Scot Copeland, and Thomas Cahill, 1995, Measurement of Aerosol Absorption Coefficient from Teflon Filters Using Integrating Plate and Integrating Sphere Techniques, *Aerosol Science and Technology*, 22:287-292.
29. U.S.EPA, 1998, *Implementation Plan: PM_{2.5} Monitoring Program*.
30. Remtech, Inc, 1999, Phased Array and Radio Acoustic Sounding System Product Information.
31. U.S.EPA, 1995, *Quality Assurance Handbook for Air Pollution Measurement Systems; Volume IV: Meteorological Measurements*, EPA/600/R-94/038d.
32. Applied Technologies, Inc., Product Information: Model ATS-100 Wind Sensor System.
33. Mesa Systems Co., 1997, Product Information: WNT Ultrasonic Anemometer.
34. Applied Technologies, Inc., 1999, Technical Description of a Sonic Anemometer/Thermometer.
35. Campbell Scientific, Inc., 1999, Product Information: Wind Speed and Direction Sensors.
36. Applied Technologies, Inc., Product Information: Model ATS-200 Temperature and Humidity Sensor System.
37. Enviro Technology Services plc, 1999, Product Information: Solar Radiation Pyranometer 095.
38. Advanced Pollution Instrumentation, Inc., Product Information: Zero Air System Model 701.

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Ambient air monitoring stations may be as simple as a pad for a particulate sampler or as complex as a complete station with ten or more pollutant monitoring instruments and complete meteorological monitoring. Configuration considerations for the simple particulate station are minimal, beyond meeting siting requirement. However, designing a full station may involve considerable thought.

Standardization of ambient air monitoring station design and configuration may be important to the ease, reliability and consistency of operation and data return. It also greatly improves maintenance and spare parts supply. If all stations within a jurisdiction are of similar configuration, the burden on a central supply and maintenance facility is simplified -- only the spare parts and replacements for the standard equipment need be stocked. In addition, standardization simplifies training of operators.

The design of the station should keep the station operator in mind, a well designed monitoring station will provide a comfortable and efficient workplace. Careful thought to safety, ease of access to instruments, and optimal work space should be given consideration. Having instruments in areas that are difficult to work in prolongs downtime and creates a disincentive to perform preventive maintenance.

Good design also provides optimal conditions for instrument operation. Temperature, humidity, light exposure, vibration, and chemical exposure all can effect instrument performance and lifetime.

Design consideration should also be given to station security, access, and durability. The location for optimal pollutant monitoring is sometimes in neighborhoods where the station operator is not entirely comfortable. In such areas, security for the instruments and the operator become significant issues. The station operator may not wish to spend time at these stations. Hence, maintenance, etc. may suffer. Vandalism of the instruments and station shelter may also significantly increase the cost of monitoring and reduce the data quality and quantity. For security the station must be in a fenced or secure area with locked gates or secure pathways. This includes the shelter itself and the area of the samplers and inlets.

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501 STATION SHELTERS

Air monitoring stations (other than stand alone particulate samplers) are usually in stand-alone trailers, purpose-rented office space, or housed in air quality agency, health department, or other public agency offices. Each of these situations presents somewhat different advantages, disadvantages, and circumstances. Regardless of the type of space housing the station, standardization of the instrument types and configuration, as much as possible, is highly recommended.

Locating air monitoring stations in trailers offers the flexibility of siting the trailer at the best possible location or to locate the monitoring in rural and remote areas. A trailer specified for a monitoring station must have sufficient insulation to prevent temperature fluctuations and provide sufficient electrical power for all instruments to be installed in the station, allowing for possible expansion of the station in future years, and station lights, heating, air conditioning, etc. In remote areas backup power and line conditioning may be needed.

A trailer used as a monitoring station, being a transportable facility, must be securely anchored to the ground to prevent movement and vibration.

Ambient monitoring stations in fixed facilities typically have fewer issues of power supply, etc. However, access to the roof to service the particulate sampler and for maintenance of the gaseous monitoring inlet can be problematic. As can be getting power for the particulate sampler. In addition, the gaseous monitor inlet must usually pass through the roof. Getting permission to make a hole in the roof for the inlet line is often difficult.

As can be seen from the above, there are pluses and minuses to both fixed monitoring stations and trailer-type stations.

502 EQUIPMENT LAYOUT

Equipment should be laid out in the station (Figure 502.1) to provide ease of access for operation and maintenance and present a pleasant working environment. The layout in Figure 502.1 is for example purposes and designed as a trailer type station. The same lay- out principles can be used for any station.

Some important points about laying out a monitoring station include:

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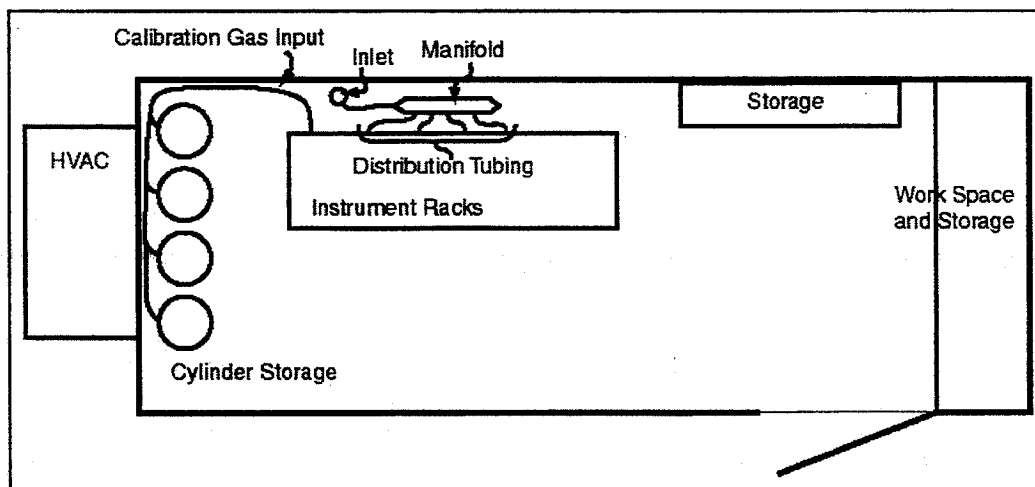


Figure 502.1 Example Shelter Layout

Work space - It's important that the station operator have a work surface on which to do paper work, instrument servicing, etc.

Storage - Storage space should be ample to allow the operator to store frequently needed spare parts and supplies. The storage space should be arranged so that everything can be stored neatly and orderly.

Clear space behind instrument rack - There should be sufficient space behind the instrument rack for the station operator to get behind the rack to work on the back side of the instruments. In addition, all tubing and electrical lines should be neatly bundled for ease of access and maintenance.

Cylinder storage - A specific location in the station should be set aside for cylinder storage. Cylinders should be clearly marked as to: pollutant contained, concentration, date of certification, and whether the cylinder is full, in use, or empty. All cylinders should be securely attached to the station wall or other fixed object to prevent their movement or falling. Tubing from the cylinders to the instruments should be clearly marked, bundled, and routed.

HVAC - the heating, ventilation, and air conditioning systems should be sized to maintain a comfortable work environment and to maintain the proper conditions for the operation of the instruments. The station must remain $25 \pm 5^{\circ}\text{C}$. To reduce the load on the heating and cooling systems, energy conservation should be taken into consideration.

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503 SAMPLING PROBES AND MANIFOLDS

Sampling probes and manifolds are important in gathering a sample of atmospheric gases and distributing them to the individual analyzers. Their key property is that they deliver an unaltered sample. The diameter, length, flow rate, pressure drop, and materials of construction are some of the variables that can affect the sample integrity.

The residence time of the sample within the sampling system (from entry into the inlet to exit into the analyzer) is critical. The federal residence time requirement is 20 seconds, while the ARB residence time requirement is less than 10 seconds. Depending upon the pollutant, cleanliness of the probe, and the amount of moisture present, the loss of pollutant in the sampling system can be appreciable. When the residence time exceeds 20 seconds the loss is detectable, at 60 seconds the sample loss can be nearly complete.

Contaminants (i.e. dirt etc.) in the sample lines and manifold can quickly degrade the sample. A dirty sample line or manifold can make the sample loss, even in a line meeting the time requirement, significant. The sample line and manifold should be cleaned regularly.

The residence time can be determined by calculating the volume of the sample line, tubing, and manifold and dividing by the total volume of sample. The residence time should be calculated for each segment of the line. The residence time in the inlet line and manifold are calculated using the total of the flow rates of all instruments on the system. From the manifold to the instrument only the flow rate of that instrument is used. For each instrument calculate the residence time as the sum of the inlet line residence time, manifold residence time, and the residence time from the manifold to that instrument. If necessary, an additional pump may be added to an extra port on the manifold to increase the flow rate and decrease the residence time in the inlet line and manifold.

Although the manifold is under a slight negative pressure, that negative pressure must not be significant. A negative pressure affects the "c" or concentration of the gas in the Beer-Lambert Law. All stations should be equipped with a Magnehelic (or similar) gauge to measure the pressure in the station manifold. The recommended pressure reading is less than 25 mm (one inch) of water.

Three general types of designs have been shown to provide the requisite unaltered sample: the vertical laminar flow manifold (Figure 503.1), the conven-

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tional manifold (Figure 503.2), and the alternate "ARB" manifold (Figure 503.3).

503.1 VERTICAL LAMINAR FLOW MANIFOLD

Figure 503.1 is an example of a vertical laminar flow manifold design. The large diameter inlet probe and laminar flow prevent the sample air from reacting with the walls of the probe. The inlet diameter of 15 cm and the flow rate of 150 liters per minute are necessary to meet the conditions of low diffusion losses. This design also minimizes the pressure drop in the inlet manifold.

Numerous materials such as glass, PVC plastic, galvanized steel, and stainless steel can be used for constructing the inlet. Removable sample lines (glass or teflon) can be inserted to extract the sample for each analyzer. This design has several advantages:

- A 15 cm diameter pipe can easily be cleaned by pulling a cloth through it with a string;
- Sampling ports can be cut into the pipe at any location and, if unused, can be plugged with stoppers of similar composition;
- Metal or PVC pose no breakage hazard; and
- There is low potential for sample contamination.

503.2 CONVENTIONAL MANIFOLD DESIGN

In practice, it is often difficult to maintain laminar flow in the vertical laminar flow manifold. The conventional manifold system (Figure 503.2) does not require laminar flow conditions; however, it must be constructed of inert materials such as glass or Teflon. The system is constructed in

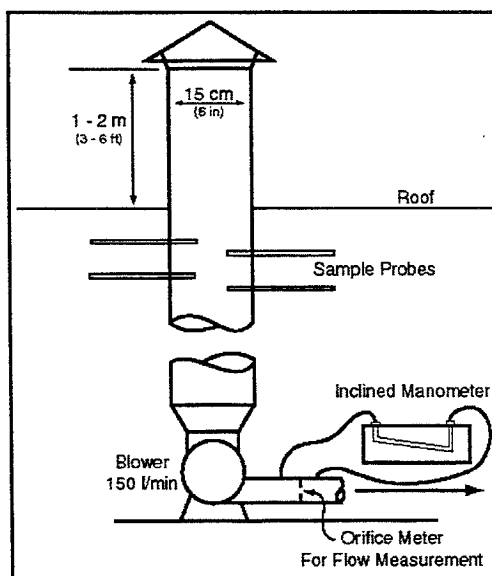


Figure 503.1 Vertical Laminar Flow Manifold

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modular units to allow easy cleaning. The system consists of a vertical "candy cane" protruding through the roof of the shelter with a horizontal sampling manifold connected by a tee to the vertical section. A bottle at the bottom of the tee collects moisture and large particulate matter before it enters the sample manifold. A blower at the exhaust of the manifold provides a flow of approximately 85 to 140 l/min through the system.

503.3 ALTERNATE "ARB" MANIFOLD DESIGN

The alternate or ARB manifold design (Figure 503.3) presents a lower profile, i.e. lower volume in the manifold, than the other designs. This reduces the need for a blower for bypass booster flow. A calibration line is usually attached to the inlet cane of this design. The calibration and audit gases are introduced as close as possible to the inlet to test the entire sampling system. Excess calibration gas is vented through the inlet. Since the ARB design maintains a lower flow than the other designs, less calibration or audit gas is needed.

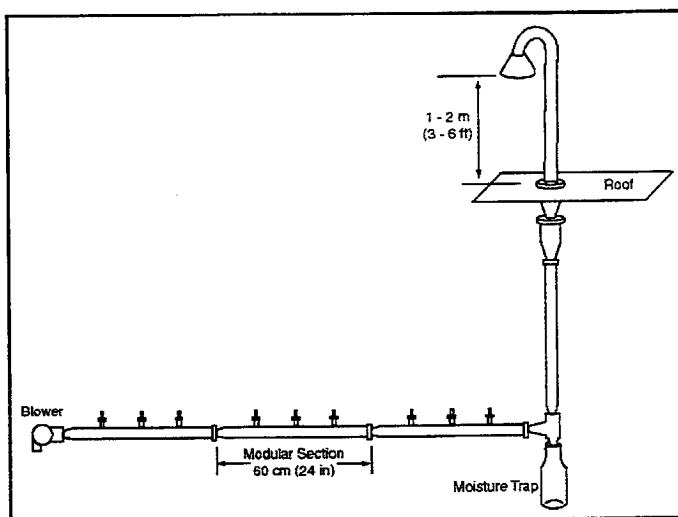


Figure 503.2 Conventional Manifold System

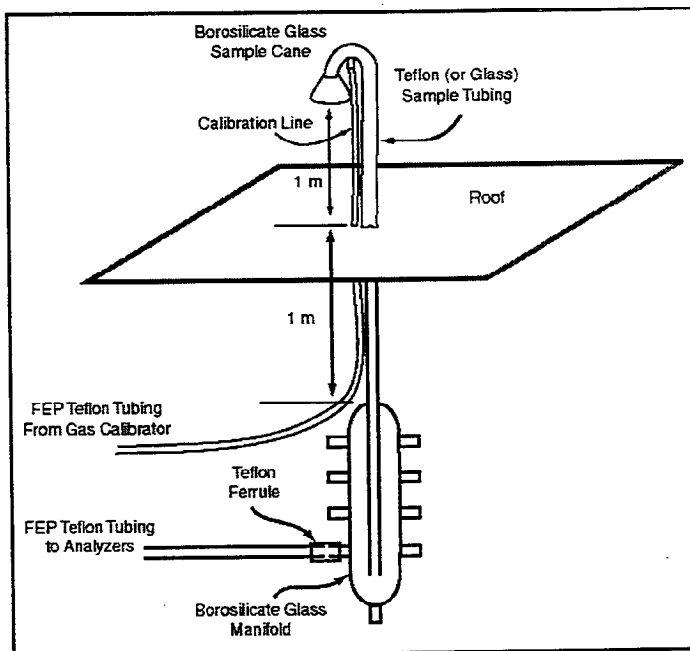


Figure 503.3 Alternate "ARB" Manifold Design

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503.4 PLACEMENT OF TUBING ON THE MANIFOLD

If the manifold has multiple ports, the placement of the tubing to the individual analyzers can be crucial (if a single analyzer is present at the station a manifold is unnecessary). If a manifold such as shown in figure 503.3 is used, tubing to instruments requiring lower flows should be placed on the lower ports. Higher flow instruments should be placed farther from the inlet into the manifold, in this case the top of the manifold.

Calibration gas should enter the system at the inlet. If injecting calibration gas at the inlet is not possible, it may be injected at the top port of the manifold. The flow rate of the calibration gas should exceed the demand of all instruments, pumps, etc. on the manifold (all instruments should be operated, including any bypass pumps in normal operating mode during calibrations) and excess calibration gas should be vented back up the inlet.

Figure 503.4 illustrates the layout and configuration of an air monitoring station using the ARB manifold.

504 PLACEMENT OF PROBES AND MANIFOLDS

The probe is the interface of the station to the general ambient air mass. As such it must be carefully located to avoid introducing bias to the sample. Important considerations are: probe height, probe length (for horizontal probes), sources of contamination, and physical influences near the probe. In general:

- Probes should not be placed near air outlets such as exhaust fans;
- Horizontal probes must extend beyond building overhangs;
- Probes should not be near physical obstructions (chimneys, roof parapets, satellite dishes, etc.) which may affect the air flow in the vicinity of the probe; and
- The height of the probe above the ground depends on the pollutant being measured and the scale of measurement.

With the exception of microscale CO monitoring (see Section 603 for discussion of monitoring scales), the inlet for gas monitors should be between 3 and 15 meters above the ground; microscale CO should be at 3 ± 0.5 meters. The inlet

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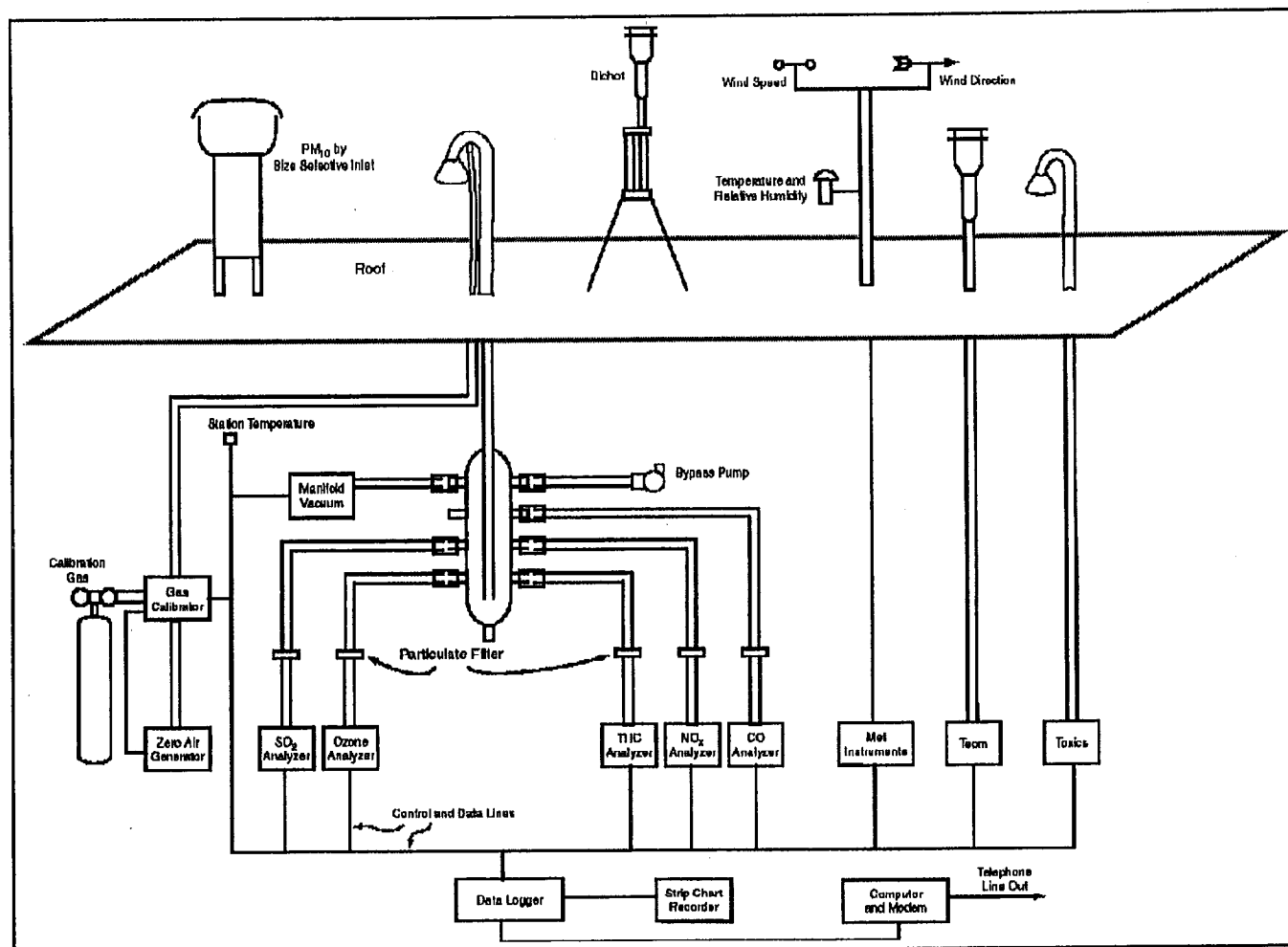


Figure 503.4 Standard ARB Ambient Monitoring Station Configuration

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for microscale particulate samples must be between 2 and 7 meters and for other scales, the particulate inlet should be between 2 and 15 meters above the ground.

There must also be at least one meter between a gas inlet and any horizontal or vertical structure. For particulate samplers, the horizontal distance to support structures must be at least two meters.

Separation between the inlets and roadways is much more complicated. The separation distance depends on the traffic volume in addition to the parameter monitored and the monitoring scale. Table 504.1 summarizes the spacing of probes from roadways. For PM_{10} and $PM_{2.5}$, Figure 504.1 provides the acceptable areas for particulate samplers with the exception of microscale street canyon samplers.

To ensure data from open path monitoring instruments are representative of the intended monitoring objectives, specific path siting criteria are outlined in 40 CFR 58, Appendix E. A middle scale path (up to 300 m in length) or a neighborhood, urban, or regional path (up to 1 km in length) must have at least 80% of its path between 3 and 15 meters above the ground for gaseous monitoring. No more than 10% of the path may be impacted by obstructions, trees, or roadways. This limit for cumulative interferences on the monitoring path controls the total amount of interference from minor sources, obstructions, roadways, and other factors that might unduly influence the open path monitoring data.

Table 504.1 Minimum Separation Distance Between Sampling Probes and Roadways

| Average Daily Traffic (vehicles per hour) | Minimum separation distance (in meters) between roadways and probes or monitoring paths at various scales | | | | | | |
|--|---|---------------------------------|-----------------------|-------------|--------------|---|------|
| | Ozone | NO ₂ | CO | Lead | | Neighborhood, Urban, and Regional Scale | PAMS |
| | Neighborhood and Urban Scale | Neighborhood and Urban Scale | Neighborhood Scale | Micro Scale | Middle Scale | | |
| ≤10,000 | 10 | 10 | 10 | 5 - 15 | >15 - 50 | >50 | >10 |
| 15,000 | 20 | 20 | 25 | | | | 20 |
| 20,000 | 30 | 30 | 45 | 5 - 15 | >15 - 75 | >75 | 30 |
| 30,000 | | | 80 | | | | |
| >40,000 | | | | 5 - 15 | >15 - 100 | >100 | |
| 40,000 | 50 | 50 | 115 | | | | 50 |
| 50,000 | | | 135 | | | | |
| >60,000 | | | 150 | | | | |
| 70,000 | 100 | 100 | | | | | 100 |
| ≥110,000 | 250 | 250 | | | | | 250 |

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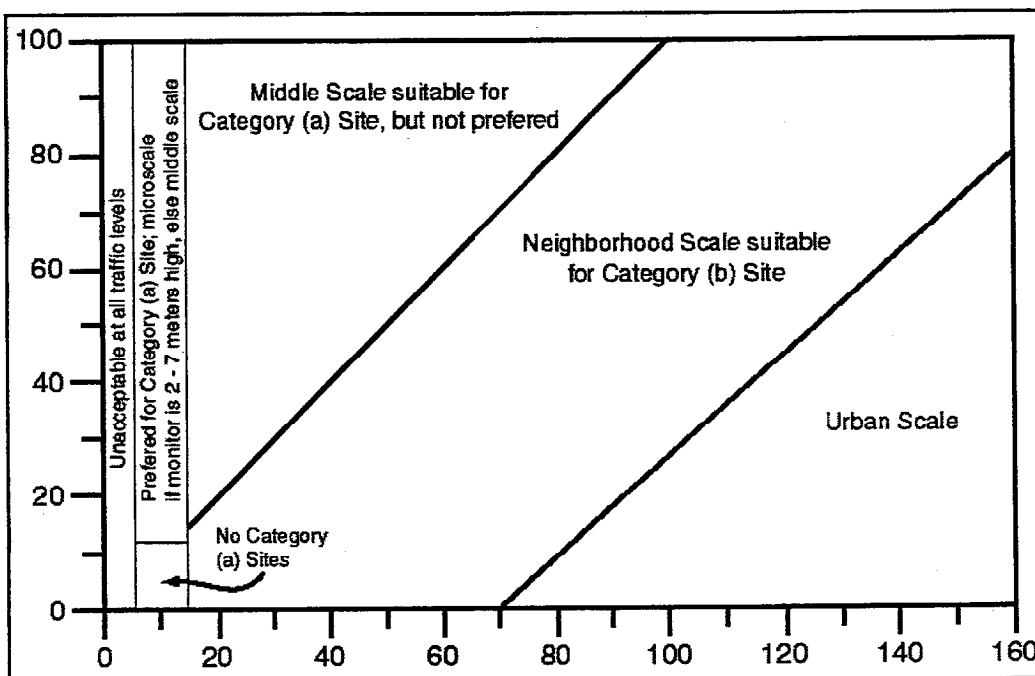


Figure 504.1 Distance of PM₁₀ and PM_{2.5} Samplers From Nearest Traffic Lane (meters)

In areas subject to frequent fog, dust, rain, and snow consideration should be given to a shortened path length to minimize data loss due to these temporary optical obstructions. In some ambient air monitoring situations shorter path lengths may be needed in order to ensure that the monitoring station meets the objectives and spatial scales defined for SLAMS.

Since open path monitors monitor a long narrow column of air, movements or instability can cause a loss of signal and less accurate readings. A concrete pillar with a wide base, placed on a stable foundation has been found to provide a suitable mount. Steel buildings and wooden platforms should be avoided since they tend to move with wind and temperatures. Metal roofing will, for example, expand when heated by the sun in the summer.

505 REFERENCES

1. *Code of Federal Regulations, Title 40, Part 50*, 1996, U.S. Government Printing Office.

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2. *Code of Federal Regulations, Title 40, Part 53*, 1996, U.S. Government Printing Office.
3. *Code of Federal Regulations, Title 40, Part 58*, 1996, U.S. Government Printing Office.
4. U.S. EPA, 1998, *Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II: Part 1 Ambient Air Quality Monitoring Program Quality System Development*, EPA-454/R-98-004.

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The selection of an ambient air monitoring station site is the essence of the definition of the monitoring effort. The impacts that local and transported air pollutants have at the monitoring station are dependant on the siting parameters selected.

Air quality samples are generally collected for one or more of the following general reasons:

- To judge compliance with and/or progress towards meeting ambient air quality standards;
- To activate emergency control procedures that prevent or alleviate air pollution episodes;
- To observe pollutant concentration trends; and
- To provide a data base for research evaluation of effects; urban, land-use, and transportation planning; development and evaluation of abatement strategies; and development and validation of diffusion models.

Depending on the reason sampling is needed, appropriate siting parameters must be selected. Improper siting of a monitoring station will render the data produced to be invalid or misleading.

For the data produced by the monitoring station to be useful, proper site selection is of critical importance. The objective, purpose, scale, etc. that have been decided as needed for the station will dictate the site requirements for representativeness. Each of these requirements cannot be considered independently, rather they are all part of the entire monitoring scenario.

The selection of a monitoring site entails four principle activities:

- Understanding the objective and purpose of monitoring;
- Identifying the most appropriate scale to satisfy the sampling need;
- Identifying the locations available for the monitoring station; and
- Coordinating the monitoring station with the existing and projected monitoring network.

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The criteria from the U.S.EPA for ambient air monitoring station siting are primarily contained in 40 CFR 58¹ and in application manuals such as the *PAMS Implementation Manual*,² *Guideline on Ozone Monitoring Site Selection*,³ *Network Design and Optimum Site Exposure Criteria for Particulate Matter*,⁴ etc.

601 MONITORING OBJECTIVES

In determining the monitoring objective the proximity of the station to population centers and emission sources is evaluated. In planning a new monitoring station, the objective category classification should be the result of an analysis of monitoring needs. These needs may be:

- To fill in blank spaces in an existing network to more fully describe the trends and patterns of pollutant concentrations;
- As a result of population and/or industrial growth additional monitoring stations may need to be added to the network;
- Concerns about emission characteristics and concentrations from existing or new sources may necessitate additional compliance oriented monitoring stations; and
- Public concerns about air pollution impacts on their lives and property.

Depending on the needs and the program in which the station will operate (i.e. the purpose; see Section 602), the monitoring station will fit as one of four SLAMS type objectives or three PAMS objectives:

- Highest concentration (SLAMS);
- Representative concentration in area of high population density (SLAMS);
- Impact of sources or source categories (SLAMS);
- General background concentration levels (SLAMS);
- Ambient pollutant concentration trend analysis (PAMS);

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- Spatial and diurnal pollutant concentration variability (PAMS); or
- Changes in VOC species profiles (PAMS).

A station may have both a SLAMS and a PAMS objective if its data are reported to both programs.

Emission inventories (point sources, area sources, and traffic data) are often the most important background information needed when designating the objective of a monitoring station. The emission data provide valuable information concerning the size and distribution of sources. Also, a model run on the emission inventory data can predict pollutant concentrations and help guide monitoring station location and scale.

An additional factor of site objective is to monitor transport of pollutants and their precursors. This is an implied factor in SLAMS locations. However, PAMS specifically calls for the consideration of transport in site selection.

602 PURPOSE OF MONITORING SITES

The purpose of monitoring refers to the program to which the data will be applied. These purposes include State and Local Air Monitoring Stations (SLAMS), National Air Monitoring Stations (NAMS), Photochemical Assessment Monitoring Stations (PAMS), Prevention of Significant Deterioration (PSD), and Special Purpose Monitoring (SPM). Details of these programs is discussed in Section 304 of this manual.

603 SCALES OF MONITORING

Since monitoring data are collected to represent the conditions in a section or subregion of a geographic area, one of the goals in siting a monitoring station is to correctly match the spatial scale represented by the sample of monitored air with the most appropriate monitoring scale for the objective of the monitoring effort. The design of a monitoring network must be carefully evaluated not only at the outset of monitoring, but also at relatively frequent intervals to be certain that conditions have not changed. The monitoring scales are:

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Micro

Concentrations in air volumes associated with area dimensions ranging from several meters up to about 100 meters (Figure 603.1)

Middle

Concentrations typical of areas up to several city blocks in size with dimensions ranging from 100 meters up to 0.5 kilometer (Figure 603.2).

Neighborhood

Concentrations within some extended area of the city that has relatively uniform land use with dimensions in the 0.5 to 4.0 km range (Figure 603.3).

Urban

Overall, citywide conditions with dimensions on the order of 4.0 to 50 km. This scale would usually require more than one site for definition (Figure 603.4).

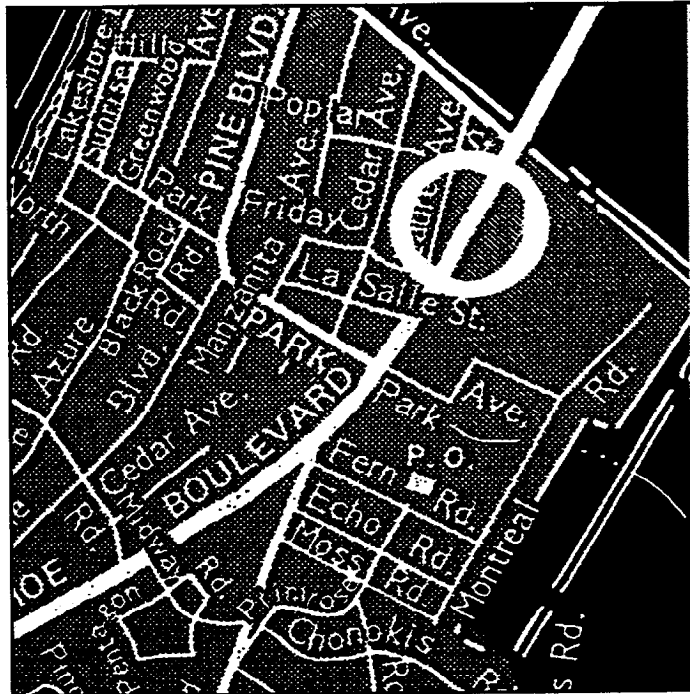


Figure 603.1 Microscale Monitoring Site

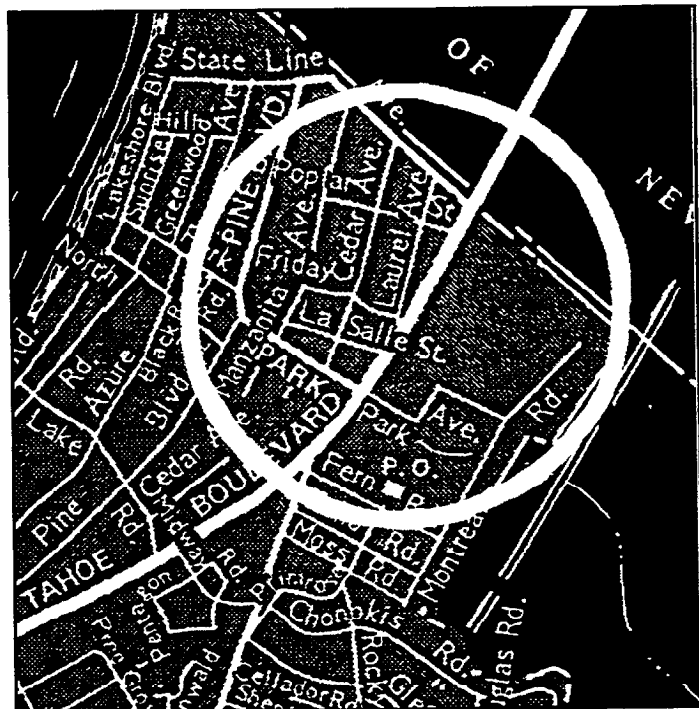


Figure 603.2 Middle Scale Monitoring Site

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Regional

Usually a rural area of reasonably homogeneous geography and extends from tens to hundreds of km (Figure 603.5).

National and Global

Concentrations characterizing the nation or globe as a whole (Figure 603.5).

603.1 DESIGN CRITERIA

The scale of monitoring must be appropriate for both the specific pollutant and the station overall for the objective and purpose of monitoring (Tables 603.1 and 603.2). Depending on the pollutant and the objective and purpose, each pollutant monitored may be representative of different scales at one monitoring station. The sites for NAMS stations are selected from the SLAMS network with an emphasis on urban and multisource areas. The NAMS monitoring areas must be selected based on urbanized population

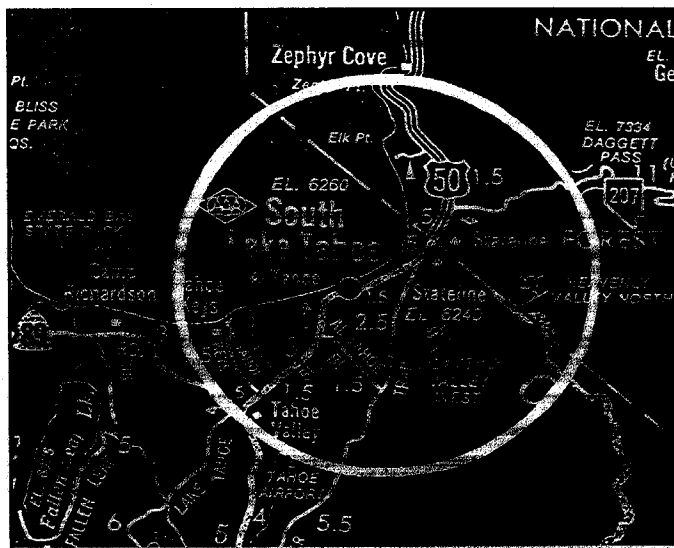


Figure 603.3 Neighborhood Scale Monitoring Site

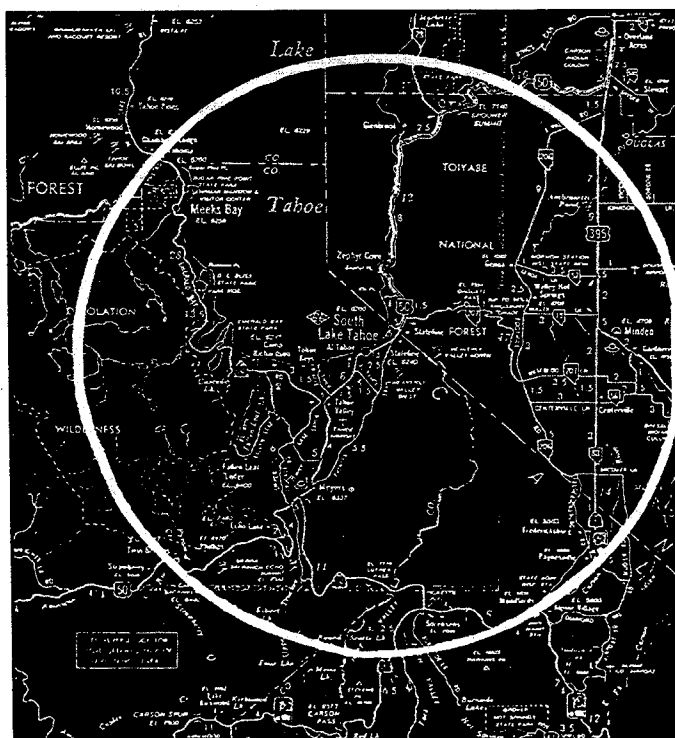


Figure 603.4 Urban Scale Monitoring Site

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and pollutant concentrations (see Section 304 of this manual).

603.1.1 Sulfur Dioxide (SO_2) Design Criteria

The spatial scales for SO_2 monitoring are the middle, neighborhood, urban, and regional scales. Because of the nature of SO_2 distributions over urban areas, if undue effects of local sources can be eliminated, middle scale measurements are most likely to be represented by a single measurement. In suburban areas where the concentration gradients are likely to be less steep, neighborhood

scale measurements are most likely to be representative. Urban scale measurements are most likely to be representative where the concentrations are uniform over a larger geographic area. Finally, regional scale measurements are most likely to be associated with rural areas.

There should be more NAMS stations in densely populated, multisource urban areas with higher SO_2 concentrations (Table 603.3). For those cases where more than one NAMS is required, there should be at least one Category (a) and one Category (b) station. The actual number of SO_2 NAMS stations in any one specific area depends on local factors such as meteorology, topography, urban and regional air quality gradients, and the potential for significant air quality improvement or degradation.

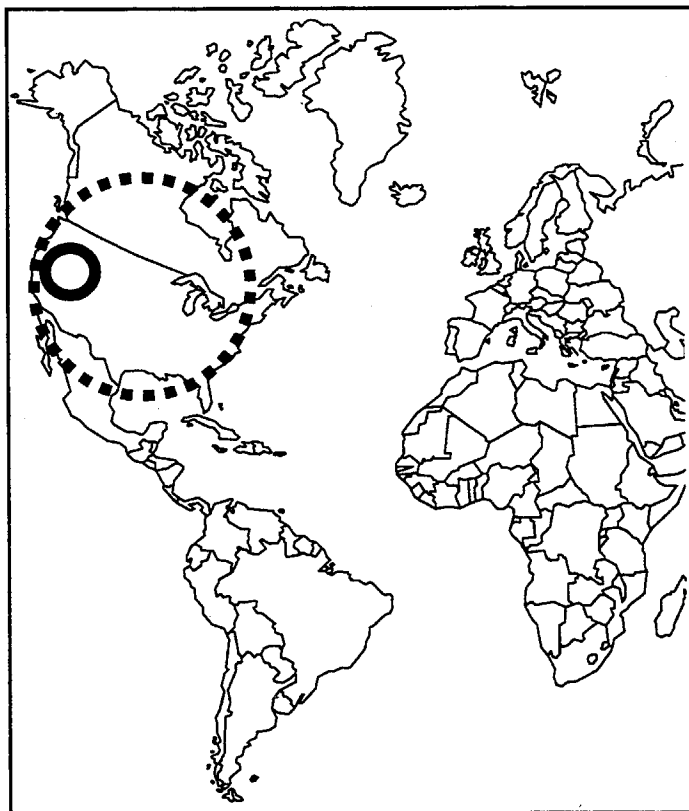


Figure 603.5 Regional (solid circle) and National/Global (dashed circle) Scale Monitoring Sites

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603.1.2 CO Design Criteria

Since CO exposures to persons is the primary concern, the smaller scales (micro, middle, and neighborhood) are required for CO monitoring. Carbon monoxide maxima typically occur in areas near major roadways and intersections with high traffic density and poor ventilation. Since these maxima can be readily modeled, a large fixed CO monitoring network is unnecessary. Long-term CO monitoring may be confined to a limited number of micro and neighborhood scale stations in a large metropolitan area to measure maximum pollution levels and to determine the effectiveness of control strategies.

An adequate NAMS network can consist of as few as two stations per major metropolitan area (i.e. urban area greater than 500,000). The two categories for which CO NAMS should be required are: (a) peak concentration areas near major traffic arteries and near heavily travelled streets in downtown areas (micro scale); and (b) neighborhoods where concentration exposures are significant (middle and neighborhood scales).

603.1.3 Ozone Design Criteria

Since ozone is the result of complex photochemistry in the atmosphere rather than being emitted as a primary pollutant, the emission sources and impact areas are separated both spatially and temporally. The separation between the primary emission sources (precursor sources) and the secondary pollutant concentration suggests

Table 603.1 Monitoring Scales For Criteria Pollutants

| Spatial Scale | Scale Applicable for SLAMS | | | | | | Scale Required for NAMS | | | | | | Scale Required for PAMS | | | |
|---------------|----------------------------|----|----------------|-----------------|----|------------------|-------------------------|----|----------------|-----------------|----|------------------|-------------------------|--------|--------|--------|
| | SO ₂ | CO | O ₃ | NO ₂ | Pb | PM ₁₀ | SO ₂ | CO | O ₃ | NO ₂ | Pb | PM ₁₀ | Type 1 | Type 2 | Type 3 | Type 4 |
| Micro | | ✓ | | | ✓ | ✓ | | ✓ | | | ✓ | ✓ | | | | |
| Middle | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | ✓ | ✓ | | | | |
| Neighborhood | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | | |
| Urban | ✓ | | ✓ | ✓ | ✓ | ✓ | | | ✓ | ✓ | | | ✓ | | ✓ | ✓ |
| Regional | ✓ | | ✓ | | ✓ | ✓ | | | | | | | | | | |

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Table 603.2 Characteristics of Spatial Scales Related to Each Pollutant

| Pollutant | Spatial Scale | Characteristics |
|-----------------|---------------|---|
| SO ₂ | Middle | Useful in assessing the effects of control strategies to reduce urban concentrations (especially for the 3-hour and 24-hour averaging times) and monitoring air pollution episodes. |
| | Neighborhood | This scale applies in areas where the SO ₂ concentration gradient is fairly flat (mainly suburban areas surrounding the urban center) or in large sections of small cities and towns. May be associated with baseline concentrations in areas of projected growth. These areas are generally homogeneous in terms of emissions and population density. |
| | Urban | Useful for the assessment of air quality trends and the effects of control strategies on urban scale air quality. |
| | Regional | Provide information on background air quality and interregional pollutant transport. Applicable to large homogeneous areas, particularly those which are sparsely populated. |
| CO | Micro | Measurements on this scale represent distributions within street canyons, over sidewalks, and near major roadways. Measurements of a particular location in the street canyon would be typical of a high concentration area which is representative of many other high concentration areas throughout the street canyon or at other similar locations in the city. Provides information for devising or evaluating "hot spot" control measures. |
| | Middle | In addition to the conventional dimensions for middle scale, for CO this category includes regions that are homogeneous for long distances along a and inhomogeneous normal to the street (i.e. an area several kilometers by tens of meters) such as strip development or freeway corridors. Also includes parking lots and feeder streets associated with indirect sources (shopping centers, stadia, office buildings, etc.). |
| | Neighborhood | Represent homogeneous urban subregions with dimensions of a few kilometers. Generally more regularly shaped than middle scale areas. |
| Ozone | Middle | Represents conditions close to sources of NO _x (such as roads) where suppression of ozone would occur. Representative of conditions over a relatively small portion of the urban area. |

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Table 603.2 Characteristics of Spatial Scales Related to Each Pollutant (cont.)

| Pollutant | Spatial Scale | Characteristics |
|------------------|------------------------|---|
| Ozone (cont.) | Neighborhood | Represents conditions throughout a reasonably homogeneous urban subregion with dimensions of a few kilometers. Useful to the understanding and definition of processes that take hours to occur and hence involve mixing and transport. Under stagnation conditions may represent peak concentration levels within the urban area. |
| | Urban | Used to measure concentrations over large portions of an urban area. Such measurements are useful for determining trends and designing area-wide control strategies. Also may be used to measure high concentrations downwind of the area having the highest precursor emissions. |
| | Regional | Used to typify concentrations over large portions of a metropolitan area and even larger area with dimensions of as much as hundreds of kilometers. May be useful for assessing ozone that is transported into an urban area. |
| NO ₂ | Middle | Characterize the public exposure to NO ₂ in populated areas. Monitors close to roadways may also be represented by measurements on this scale. |
| | Neighborhood and Urban | Same considerations as for ozone. |
| Lead | Micro | Would typify areas such as downtown street canyons and traffic corridors where the general public would be exposed to maximum concentrations from mobile sources. Because of the very steep ambient Pb gradients resulting from Pb emissions from mobile sources, the dimensions of the micro scale for Pb generally would not extend beyond 15 meters from the roadway. |
| | Middle | Represents Pb air quality levels in areas up to several city blocks in size (approximately 100 to 500 meters). The dimensions for a middle scale roadway type station would be on the order of 50 to 150 meters because of the exponential decrease in lead concentration with increasing distances from roadways. Important middle scale sites include schools and playgrounds in central city areas which are close to major roadways. Emissions from stationary sources may impact on areas at which single sites may be located to measure concentrations representing middle scales. |
| | Neighborhood | Would characterize air quality conditions throughout a relatively uniform area representative of an area where children live and play. |

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Table 603.2 Characteristics of Spatial Scales Related to Each Pollutant (cont.)

| Pollutant | Spatial Scale | Characteristics |
|-------------------|---------------|---|
| Lead (cont.) | Urban | Would represent ambient Pb concentrations over an entire metropolitan area. Useful for assessing trends in city-wide air quality and the effectiveness of larger scale air pollution control strategies. |
| | Regional | This large scale of representativeness would be most applicable to sparsely populated areas and could provide information on background air quality and interregional pollutant transport. |
| PM ₁₀ | Micro | Areas such as downtown street canyons and traffic corridors where the general public would be exposed to the maximum concentrations from mobile sources; generally not extending more than 15 meters from the roadway, but could continue the length of the roadway (several kilometers). Emissions from stationary sources may, under certain plume conditions, result in high ground level concentrations at the microscale. |
| | Middle | Much of the measurement of short term public exposure is on this scale. This scale also includes the characteristic concentrations for other areas with dimensions of a few hundred meters such as parking lots and feeder streets associated with shopping centers, stadia, and office buildings. Unpaved or seldom swept parking lots associated with these sources could be an important source in addition to the vehicular emissions themselves. |
| | Neighborhood | Measurement in this category would represent conditions throughout some reasonably homogeneous (including land use and surface characteristics) and regularly shaped urban subregion including commercial, industrials, and residential areas. These stations provide information about trends and compliance with standards. |
| | Urban | Characterizes concentrations over an entire metropolitan area. Useful in assessing trends and effectiveness of air pollution control strategies. |
| | Regional | Characterizes concentrations over large, sparsely populated areas with reasonably uniform ground cover. Provides information about larger scale PM ₁₀ emissions, losses, and transport. |
| PM _{2.5} | Micro | Areas such as downtown street canyons and traffic corridors where the general public can be expected to be exposed to maximum concentrations from mobile sources. Core SLAMS on the microscale should be limited to urban sites that are representative of long term human exposure and of many such microenvironments in the area. |

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Table 603.2 Characteristics of Spatial Scales Related to Each Pollutant (cont.)

| Pollutant | Spatial Scale | Characteristics |
|------------------------------|---------------|--|
| PM _{2.5} (cont.) | Middle | Measurements of this type would be appropriate for the evaluation of possible short-term exposure public health effects of particulate matter pollution. This scale includes the characteristic concentrations for other areas with dimensions of a few hundred meters such as the parking lot and feeder streets associated with shopping centers, stadia and office buildings. |
| | Neighborhood | Measurements in this category would represent conditions throughout some reasonably homogeneous urban subregion generally more regular in shape than middle scale regions. Much of the PM _{2.5} exposures are expected to be associated with this scale of measurement. This category includes industrial, commercial, and residential neighborhoods. |
| | Urban | This class of measurement would be made to characterize the particulate matter concentrations over an entire metropolitan or rural area. Such measurements would be useful for assessing trends in area-wide air quality and the effectiveness of large scale air pollution control strategies. |
| | Regional | These measurements would characterize conditions over areas with dimensions of as much as hundreds of kilometers. Using representative conditions for an area implies some degree of homogeneity in that area. For that reason, regional scale measurements would be most applicable to sparsely populated areas with reasonably uniform ground cover. Data characteristics of this scale would provide information about larger scale processes of particulate matter emissions, losses, and transport. |
| PAMS | Neighborhood | Represent conditions throughout a homogeneous neighborhood scale urban subregion. Precursor concentrations on this scale will become well mixed and can be used to assess exposure impacts and track emissions. Neighborhood data will provide information on pollutants relative to residential and local business districts. VOC sampling at type 2 sites is characteristic of a neighborhood scale. Measurements of these reactants are ideally located just downwind of the edge of the urban core emission areas. |
| | Urban | Would represent concentration distributions over a metropolitan area. Monitoring on this scale relates to precursor emission distributions and control strategy plans for an MSA/CMSA. PAMS type 1, 3, and 4 sites are characteristic of the urban scale. |

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that the meteorological conditions and transport processes play an important part in the development of the network design criteria. The placement of monitoring stations to measure peak transport, peak local (under normal conditions), and peak ozone under stagnation conditions is highly dependant on the meteorological conditions and most likely will be at quite different locations.

Table 603.3 SO₂ and PM₁₀ NAMS Station Criteria

| Population Category | Sulfur Dioxide | | | PM ₁₀ | | |
|----------------------|---------------------|----------------------|-------------------|--------------------|----------------------|-------------------|
| | High Concentrations | Medium Concentration | Low Concentration | High Concentration | Medium Concentration | Low Concentration |
| >1,000,000 | 6 - 10 | 4 - 8 | 1 - 4 | 6 - 10 | 4 - 8 | 2 - 4 |
| 500,000 to 1,000,000 | 4 - 8 | 2 - 4 | 1 - 2 | 4 - 8 | 2 - 4 | 1 - 2 |
| 250,000 to 500,000 | 3 - 4 | 1 - 2 | 0 - 1 | 3 - 4 | 1 - 2 | 0 - 1 |
| 100,000 to 250,000 | 1 - 2 | 0 - 1 | 0 | 1 - 2 | 0 - 1 | 0 |

The principle spatial scales for SLAMS purposes are neighborhood, urban, regional, and to a lesser extent, middle scale. Since ozone requires appreciable formation time and the mixing of reactants occurs over large volumes of air, monitoring of small scale variations in concentrations is reduced.

Each urban area with a population of 200,000 or more will generally require two NAMS ozone monitoring stations. The 200,000 cutoff was selected due to the diverse nature of hydrocarbon sources (both mobile and stationary) and the need for better understanding of the ozone problems and their control strategies. Two stations are sufficient for most urban areas since the spatial gradients for ozone are generally not as steep as for other criteria pollutants.

One of the ozone NAMS stations must be representative of the maximum ozone concentrations (category (a), urban scale) under transport conditions. This site must balance local factors affecting transport and the buildup of peak ozone levels with the need to represent population exposure. The second NAMS site should be representative of high density population areas on the fringe of the central business district along the principle summer wind direction. This second station should be a category (b), neighborhood scale station and will measure peak ozone concentrations under light and variable or stagnant wind conditions.

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Since ozone concentrations are highly dependant on solar radiation and temperatures, monitoring for ozone at NAMS and SLAMS sites is only required during the "ozone season" when the ozone formation potential is significant. In many southern and western states (including California) the ozone season is year round. On the other hand, the ozone season in northern states may be as short as from June until September (Montana and South Dakota). The ozone season for most states is from April until October.

603.1.4 Nitrogen Dioxide (NO₂) Design Criteria

Most nitrogen oxide sources emissions are in the form of NO as opposed to NO₂, which is monitored and regulated. The NO₂ is a secondary pollutant (in most cases) formed through atmospheric chemistry. Since NO₂ is formed by oxidation of NO in the atmosphere, large volumes of air and significant mixing times are required and, hence, the importance of the smaller scales of monitoring are less important. The typical spatial scales of NO₂ monitoring are primarily neighborhood and urban scales, although there are some situations in which middle scale measurements would be made.

The maximum NO₂ concentrations should be expected to be found slightly downwind of the maximum total nitrogen oxides concentrations. This is to allow time for maximum formation of NO₂. A balance must be struck between the dilution of concentrations with downwind distance and the formation rate. Since their chemistry is interrelated, the location of high NO₂ is often correlated with the location of high ozone concentrations. The distance and direction downwind to expect the maximum NO₂ should be based on the ozone season wind patterns.

Nitrogen dioxide concentrations are likely to decline rather rapidly outside the urban area. Therefore, the best location for measuring NO₂ will often be in neighborhoods near the edge of the city.

The NAMS NO₂ monitoring is primarily required only in large (population in excess of 1,000,000) urban areas. This is sufficient to generate data for a national analysis of the data. Also, NO₂ problems generally occur in these large urban areas.

Within the large urban areas requiring NAMS for NO₂, two monitoring stations are usually sufficient. The first station (category (a), middle or neighborhood scale) would be to measure the photochemical production of NO₂ and would

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best be located in the part of the urban area where most nitrogen oxides are emitted. The second station (category (b), urban scale), would be to measure the NO_2 produced from the reaction of NO with ozone and should be downwind of the area of peak NO_x emissions.

603.1.5 Lead (Pb) Design Criteria

Historically, lead emissions have been overwhelmingly automotive with a small portion from stationary sources. With the removal of lead from gasoline, the atmospheric concentrations have dramatically fallen and are today largely stationary source in nature. In January 1999 the EPA revised the lead NAAQS to better reflect the change in the principle lead emission sources from onroad mobile sources to stationary sources.⁵ Future lead monitoring will emphasize monitoring focused around point sources rather than mobile sources. Currently all air quality problems in populated areas are due to local point sources like lead smelters or battery plants.⁶

The most important spatial scales to characterize the emissions stationary sources are the micro, middle, and neighborhood scales. For purposes of measuring larger scale homogeneous areas urban or regional scales may also be needed.

Monitoring for ambient lead is required for all major urbanized areas where the levels have been shown to be (or are expected to be) of concern due to the proximity of lead point source emissions. Sources emitting at least 4.5 Mg (5 tons) per year are candidates for lead monitoring. The total number and type of stations for SLAMS are not prescribed, but must be determined on a case-by-case basis. At a minimum there must be at least two stations where lead concentrations currently exceed, or have exceeded the Lead NAAQS at some time during the past eight quarters. At least one of the stations must be a category (a) type station; the other station may be either category (a) or (b) depending on the extent of the source's impact and the existence of residential neighborhoods surrounding the source.

A NAMS station must be located in one of the two largest cities in each of the ten EPA Regions in the country. In addition, one NAMS site must be located in each of the MSA/CMSA's where one or more violations of the quarterly lead NAAQS have been recorded within the previous eight quarters. If a violation of the quarterly NAAQS is measured at a monitoring site outside of a MSA/CMSA, one NAMS site must be located within the county in a populated area to

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assess area wide lead air pollution levels. These NAMS sites should represent the maximum lead concentrations measured within the MSA/CMSA, city, or county that is not directly affected by a single lead point source. In order to verify that onroad mobile sources do not contribute to a lead NAAQS, roadside sites should be considered viable NAMS site candidates. A NAMS site may be a micro or middle scale category (a) station located adjacent to a major roadway, or a neighborhood scale station that is located in a highly populated residential area where the traffic density is high.

603.1.6 Particulate Matter (PM_{10} and $PM_{2.5}$) Design Criteria

The most important spatial scales to effectively characterize the emissions of particulate matter from both mobile and stationary sources are the middle scale for PM_{10} and neighborhood scale for both PM_{10} and $PM_{2.5}$. For larger homogeneous areas and to characterize regional transport, urban and regional scale stations may also be needed. Most $PM_{2.5}$ monitoring in urban areas should be representative of a neighborhood scale.

Specific Design Criteria for $PM_{2.5}$

The design criteria of the $PM_{2.5}$ monitoring network are more complex than those for other pollutants. The goal of this more complex process is to obtain measurements that are more representative of the monitored community. The design criteria for the $PM_{2.5}$ network are based on monitoring planning areas (MPAs) that correspond to metropolitan statistical areas (MSAs) with a population of 200,000 or more and other areas that are in violation of the $PM_{2.5}$ standard.⁷ The MPAs are defined by the boundaries of states, counties, zip codes, census blocks, or census block groups.

The annual standard is generally the controlling standard for lowering both short- and long-term $PM_{2.5}$ concentrations on an area-wide basis. For comparison to the annual NAAQS, the monitors should be neighborhood scale community-oriented locations. Population-oriented microscale (localized hot-spot) or unique population-oriented middle-scale impact sites may only be used for comparison to the 24-hour $PM_{2.5}$ NAAQS.

Rather than the number of monitoring stations being defined in the regulations, the number of stations is contained in a monitoring network proposed by the states and approved by the EPA in accordance with 40 CFR 58.20. Within each MPA, there must be at least one core SLAMS site and as many other $PM_{2.5}$

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monitoring stations as judged necessary to satisfy the SLAMS requirements. Additional stations, in addition to the minimum number of core stations, are recommended. The additional core SLAMS are not required to sample more often than one day in three.

Core monitoring stations are a subset of the SLAMS network that are sited to represent community-wide air quality. The core stations may be collocated at PAMS monitoring stations. An MSA with a population of between 200,000 and 500,000 must have at least one core $PM_{2.5}$ monitoring stations sampling every third day. An MSA of greater than 500,000 persons must have at least two core $PM_{2.5}$ SLAMS sampling everyday, including at least one station in a population-oriented area of expected maximum concentration (analogous to a NAMS category (a) site) and at least one station in an area of poor air quality and high population impact (analogous to a NAMS category (b) site). There must also be at least one additional core monitor collocated at a PAMS site if the MPA is also a PAMS area. Larger MSAs (population greater than 1,000,000) must have additional core SLAMS as specified in Table 603.4.

**Table 603.4
Required Number of
Core SLAMS
According to MSA
Population (core sites
at PAMS are in addition to
these numbers)⁷**

| MSA Population | Minimum Required Number of Core Sites |
|-------------------|---|
| >1 Million | 3 |
| >2 Million | 4 |
| >4 Million | 6 |
| >6 Million | 8 |
| >8 Million | 10 |

Those MPAs with several different and geographically disjoint particulate sources should have separate core sites to monitor each influencing source region. However, areas with two or more core monitors may be averaged for comparison with the annual $PM_{2.5}$ NAAQS if the area exhibits relatively uniform annual average air quality (average concentrations at individual sites do not exceed the spatial average by more than 20%) and similar day to day variability (correlations better than approximately 0.6). Such an averaged area is termed the community monitoring zone (CMZ). The entire CMZ should be affected by the same major $PM_{2.5}$ emission sources.

At least one continuous fine particulate analyzer (BAM, TEOM, transmissometer, nephelometer etc.) is required in each metropolitan area with a population greater than 1,000,000. These analyzers provide improved temporal resolution to better understand the process and causes of elevated $PM_{2.5}$ concentrations and to facilitate public reporting of $PM_{2.5}$ air quality.

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In addition to the core SLAMS, background and regional transport $PM_{2.5}$ monitoring stations are required. These stations must be at community oriented stations. In addition, for every 200,000 persons in the monitoring planning area outside the MSA(s) containing the required core SLAMS, an additional SLAMS must be established. These additional sites may be anywhere in the state.

Particulate Matter Design Criteria for NAMS

Table 603.5 indicates the approximate number of PM_{10} stations required in MSAs to characterize PM_{10} air quality trends and geographical patterns. A range of monitoring stations is listed in the table because sources and local control efforts vary from place to place. With the implementation of the $PM_{2.5}$ monitoring, the number of PM_{10} SLAMS stations is expected to decline, but the requirement to maintain PM_{10} NAMS remains in effect.

Table 603.5 Number of PM_{10} NAMS Stations Required

- 1 - Ambient concentrations exceeding either PM_{10} NAAQS by 20% or more
2 - Ambient concentrations exceeding 80% of the PM_{10} NAAQS
3 - Ambient concentrations less than 80% of the PM_{10} NAAQS

| Population Category | High Concentration ¹ | Medium Concentration ² | Low Concentration ³ |
|---------------------|---------------------------------|-----------------------------------|--------------------------------|
| >1,000,000 | 6 - 10 | 4 - 8 | 2 - 4 |
| 500,000 - 1,000,000 | 4 - 8 | 2 - 4 | 1 - 2 |
| 250,000 - 500,000 | 3 - 4 | 1 - 2 | 0 - 1 |
| 100,000 - 250,000 | 1 - 2 | 0 - 1 | 0 |

A subset of the core $PM_{2.5}$ SLAMS and SLAMS stations intended for monitoring transport must be designated as NAMS. In an MSA where more than one NAMS is required, both category (a) and (b) must be established. If only one station is required, it must be a category (a) station. The largest urban areas (with a population greater than 1,000,000) are required to have at least one $PM_{2.5}$ NAMS.

The total number of $PM_{2.5}$ NAMS per EPA Region is based on a recommendation by the Regional Office and summarized in Table 603.6. The selected stations should represent the range of conditions occurring and consider factors such as the number and type of sources, ambient concentrations, and regional

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transport. This approach gives flexibility in establishing the network and helps balance the national network with respect to geographic areas and populations.

603.1.7 PAMS Design Criteria

Unlike the SLAMS and NAMS design criteria, PAMS design criteria are site specific rather than pollutant specific. The design criteria are based on selection of an array of monitoring sites relative to the emission and transport of ozone precursors and ozone exceedance events (see Section 304.1.3).

604 LOCATION OF MONITORING STATIONS

To select locations for monitoring, it is necessary to have detailed information on the location and strength of emission sources, the geographic variability of ambient pollutant concentrations, meteorological conditions, and the population distribution and density. From this information (and specific monitoring rule requirements) decisions as to the general areas to be monitored and the types and scales of the monitoring stations can be made. In addition to selecting the best location from an air quality and population basis, some additional factors such as economics, security, and practicality must be considered in the decisions. Some monitoring programs, such as PAMS, have an overall array pattern required as part of the monitoring program; i.e., upwind, downwind, urban core, etc. sites in specified general areas are required to be established.

604.1 URBANIZATION

The urbanization of a monitoring station describes its location within the urban area. Urbanization may be categorized as city center (city core, residential, and industrial), suburban, rural, and remote. The urbanization is frequently related to the spatial scale. Often, sites in the city core are micro or middle scale sites while those sites in remote areas tend to be regional scale.

**Table 603.6 Number of
PM_{2.5} NAMS By EPA
Region**

| EPA Region | Number of NAMS | Percent of National Total |
|------------|----------------|---------------------------|
| 1 | 15 to 20 | 6 to 8 |
| 2 | 20 to 30 | 8 to 12 |
| 3 | 20 to 25 | 8 to 10 |
| 4 | 35 to 50 | 14 to 20 |
| 5 | 35 to 50 | 14 to 20 |
| 6 | 25 to 35 | 10 to 14 |
| 7 | 10 to 15 | 4 to 6 |
| 8 | 10 to 15 | 4 to 6 |
| 9 | 25 to 40 | 10 to 16 |
| 10 | 10 to 15 | 4 to 6 |

604.2 ATMOSPHERIC CONSIDERATIONS

When selecting the location for a monitoring station, the meteorology and atmospheric effects associated with buildings, terrain features, heat sources/sinks, etc. must be considered. Meteorology is important in determining not only the geographical location of the monitoring station, but also such factors as the height, direction, and extension of sampling probes. The following three meteorological factors can greatly influence the dispersal of pollutants:

- **Wind speed** - affects the travel time from the source to the monitoring station and the dilution of the pollutant. The concentrations of pollutants are inversely proportional to the wind speed. If the pollutant is a secondary pollutant, the concentration of the pollutant will be directly proportional to the travel time and the concentration of the precursor will be indirectly proportional to the travel time (up to the maximum potential concentration).
- **Wind direction** - influences the general movement of pollutants in the atmosphere. The wind direction will determine which pollutants from which sources will arrive at the monitoring site.
- **Wind variability** - refers to the random vertical and horizontal velocity components of the wind (i.e. turbulence). These motions can be caused by either mechanical (structures and terrain features) or thermal (heating and cooling of land masses, bodies of water, etc.) features over which the plume travels. If the scale of the turbulence is larger than the size of the pollutant plume, the turbulence will move the entire plume and cause looping and fanning; if smaller, it will cause the plume to diffuse and spread out.

Other meteorological conditions to consider are atmospheric stability and the lapse rate. Meteorological conditions, particularly those that can affect light transmission (the influence of relative humidity, fog, heavy snow, haze, etc.), are extremely important in selecting the location for open path analyzers.

A wind rose (Figure 604.1) is a convenient means of evaluating meteorological conditions at a particular site. A wind rose provides a graphical depiction of the frequencies of wind speeds and directions. From the wind rose the primary wind directions can easily be seen, providing a tool in evaluating the site characteristics, identifying any potential major emission sources that may impact the site, the expected frequency of significant transport, and the expected frequency of stagnation periods.

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604.3 TOPOGRAPHY

In areas of complex topographical features, such as California, an analysis of the effect of those features on the transport and diffusion of pollutants is critical in evaluating a monitoring location. Minor features may have localized effects, important to the precise location and orientation of the station and probes. Larger features cause consider-

ably larger scale effects and, hence, have greater effects on the station location. A minor feature may be features such as a rock outcropping which may block direct flow to the station and require minor relocation of the site or probe. Major features, such as deep river valleys or mountains may completely divert the air

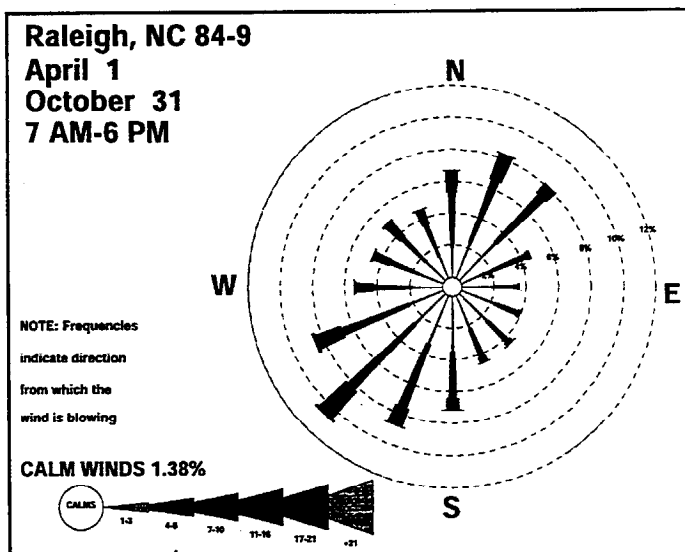


Figure 604.1 Example Wind Rose

Table 604.1 Relationships of Topography, Air Flow, and Monitoring Site Selection

| Topographical feature | Influence on air flow | Influence on monitoring site selection |
|---------------------------------|--|--|
| Slope/Valley | Down air currents at night and on cold days; up slope winds on clear days when valley heating occurs. Slope winds and valley channeled winds; tendency toward down-slope and down valley winds; tendency toward inversions | Slopes and valleys as special sites for air monitors because pollutants generally are well dispersed with the valley; concentration levels not representative of other geographic areas; possible placement of monitor to determine concentration levels in a population or industrial center in valley |
| Water | Sea or lake breezes inland or parallel to shoreline during the day or in cold weather; land breezes at night | Monitors on shoreline for background readings or for data relative to water traffic |
| Hill | Sharp ridges causing turbulence; air flow around obstructions during stable conditions, but over obstructions during unstable conditions | Depends on source orientation; upwind source emissions generally mixed down the slope, and siting at foot of hill not generally advantageous; downwind source emissions generally down washed near the source; monitoring close to a source generally desirable if population centers adjacent or if monitoring protects workers |
| Natural or man-made obstruction | Eddy effects | Placement near obstructions does not generally give representative readings |

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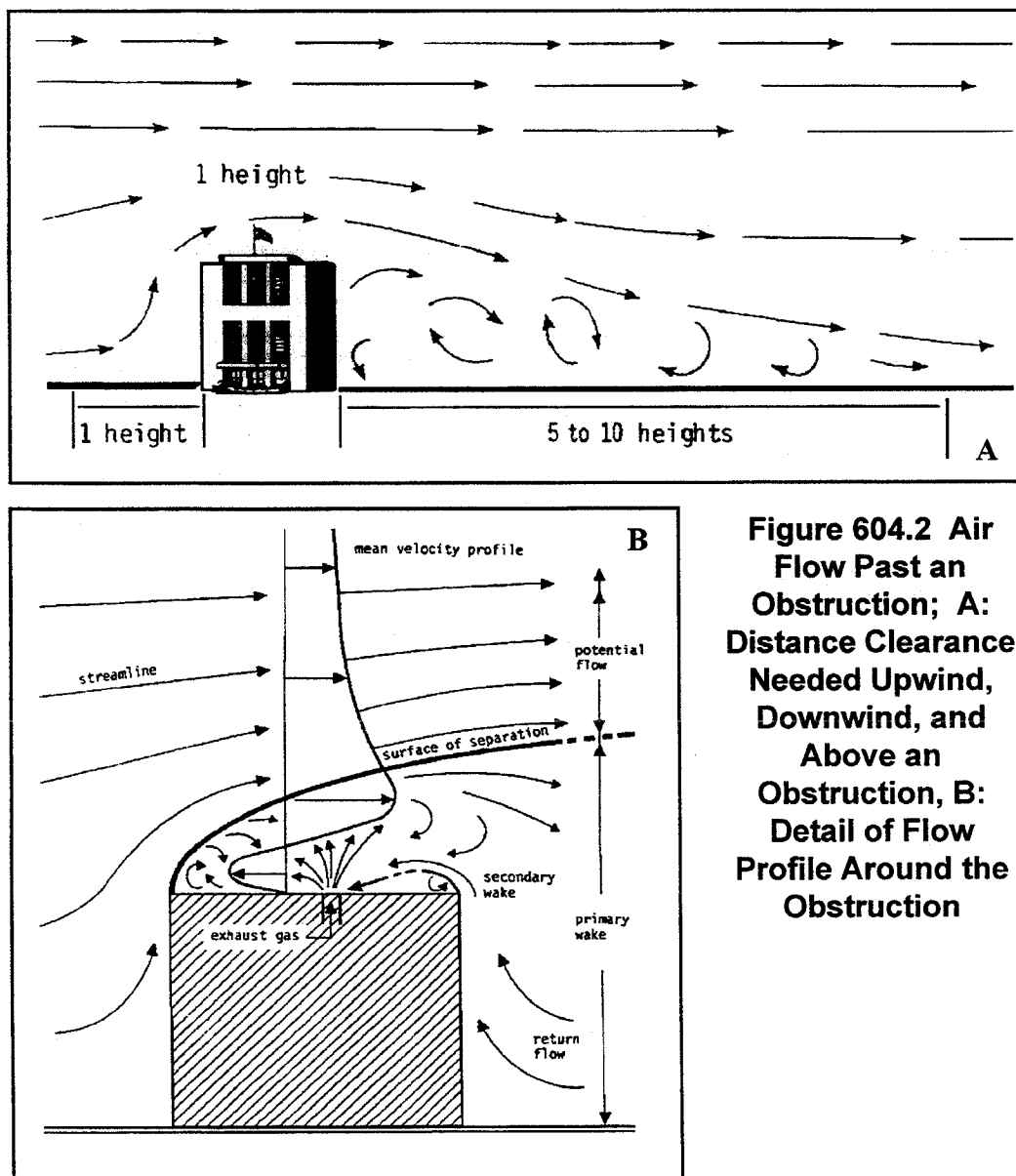


Figure 604.2 Air Flow Past an Obstruction; A: Distance Clearance Needed Upwind, Downwind, and Above an Obstruction, B: Detail of Flow Profile Around the Obstruction

mass and require monitoring at a different location possibly kilometers away. Topographic maps, available from the U.S. Geological Survey (USGS), are useful in examining the topography of the monitoring station location. Table 604.1 summarizes important topographical features and their effects on air flow.

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604.4 OBSTRUCTIONS

Because obstructions such as trees, fences, and buildings can significantly alter the air flow, monitors should be placed well away from their influence.^{8,9,10} As can be seen in Figure 604.2, the perturbed air flow extends a significant distance around (especially downwind) an obstruction. The monitoring bias due to the obstruction can be especially pronounced for particulate monitoring since particulate matter may segregate along the airflow streamlines. In addition, as indicated in Figure 604.2B, in the case of a building as the obstruction, the area of reduced pressure above the building can draw emissions out of the building. A map of the area surrounding the sampling station should be drawn indicating all the potential obstructions. The map should be updated on a regular basis to identify newly constructed buildings, trees, etc. that qualify as obstructions, but were not present when the sampling station was installed.

604.5 EMISSION SOURCES

An important aspect of ambient air monitoring is to know the potential sources of the pollutants being monitored. These sources may be obvious, such as the refinery across the street from the station, or less obvious such as pollutants transported to the site from great distances or small, local, or intermittent sources. For example, if the monitor is located on or around a fire station or hospital, the emergency generator should be identified and avoided.

604.5.1 Stationary Sources

Visual observations, aerial photography, and surveys can be useful in determining the exact locations of pollutant sources in the area surrounding the sampling location. Once the sources have been found, a map of where each is should be made and updated on a regular basis. The station operator should remain aware of activities whose zone of influence will include the monitoring station.

The zone of influence of an emission source is the area over which the emissions will have a significant impact. The zones of influence of emissions can be determined in three ways:¹¹

- gridded concentration fields can be examined to identify the concentration gradients;

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- a series of regressions of site concentrations versus emissions density can be carried out; and
- a dispersion model can be used to estimate the area of influence.

The specific areas of influence depend on season of the year and meteorological conditions. However, examination of the area of influence for surrounding sources give important factors in station location and spatial representativeness determination.

604.5.2 Mobile Sources

In a manner similar to stationary sources, mobile sources within the spatial representativeness zone of the monitoring station should be identified. The distance to roads and highways in the area should be recorded along with the average traffic volume. In California the traffic volume can be obtained from the California Department of Transportation (CalTrans). Especially in growing areas, the station operator should periodically review the mobile source impact as new roads and highways are built in the vicinity.

604.6 DOMINANT INFLUENCES

After analyzing the urbanization, topography, and obstacles affecting a monitoring station and the emission sources which impact the site, the dominant influence at the station can be determined from the sum of all these influences and effects. If this matches the goals of the monitoring program, the sites may be an appropriate location for the station. The dominant influence is usually categorized as: industrial, residential, commercial, vehicular, near urban, agricultural, recreational area, or other.

605 NETWORK DESIGN

Very rarely is a monitoring station sufficient on its own to describe the air quality of an area; a coordinated network of stations is generally required to more fully describe the region. Considerable thought must go into the design of a network to make the best use of available funds and achieve the greatest data return.

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605.1 BACKGROUND INFORMATION

In addition to the above information gathered when determining the monitoring station location, several items of background information are important when establishing a monitoring network. Principle in these are the uses foreseen for the data collected by the network and what previous (or other existing) monitoring data is available.

605.1.1 Uses of Data

Data produced by ambient air quality measurements can have a number of uses. Each use carries with it special requirements about the equipment, locations, sampling schedule, etc. of the monitoring network. The most important and common use of monitoring data is for evaluation of ambient air quality for comparison to the NAAQS or state air quality standards. In addition, the data may be useful for development and testing of air quality models, enforcement of source-specific regulations, evaluation and development of control plans, for aid in making land use or planning decisions, and for general air quality research.²²

Compliance with the NAAQS and state ambient air quality standards are fundamental goals of the ambient air monitoring strategies (particularly for SIPs) and form the basis for air quality planning, and regulatory and policy development. The data are also used to demonstrate progress toward attainment or predict long-term trends.

It can be argued that all air quality monitoring is ultimately oriented to public health concerns. Air quality indices generated by monitoring are instrumental in keeping the public apprised of current levels of air contaminants. Siting of stations to obtain data about public exposure often largely involves documentation of population exposures. The siting requirements may also involve siting monitoring stations to provide data that can be coordinated with the needs for emergency episode response. Special monitoring sites may be needed to address citizen complaints and to evaluate connections of air quality and public health in epidemiological studies.

As part of the SIP developed by the states, monitoring data is an important factor in developing and evaluating the required control plans. The monitoring data are needed to:

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- define any nonattainment areas;
- develop control policies and strategies;
- define nondeterioration areas; and
- develop air pollution emergency episode plans.

The monitoring data may be used as part of the SIP process to identify, demonstrate, and characterize the need for controls and to identify the target source categories or specific sources.

Monitoring data can be necessary for documenting the baseline conditions for environmentally sound development and expansion. Programs such as PSD often require that monitoring be conducted before a permit can be issued for construction or modification of a source facility. Site-specific monitoring stations may be required for these data, or, if existing stations provide adequate data, those existing stations may be sufficient.

In some cases, ambient air monitoring requirements for source-specific monitoring are included in permits for source facilities. The conditions and procedures for the monitoring network oriented to the facility may be negotiated between the regulatory agency and the facility. Although the objective is to measure the source specific impact, the responsibility for the network may fall on the facility or the regulatory agency. Indications of compliance or noncompliance may be used in enforcement proceedings. A related monitoring situation would entail isolating a specific source when an adverse impact has been measured.

Monitoring requirements to support model development or testing are generally unique for each project. This is particularly true for model development support where the objective is to describe and understand the ongoing processes or to develop parameter values representative of a specific terrain, meteorological condition, or source configuration. As a general rule, monitoring for model development must be intensive and flexible to provide the maximum benefit. Measurements are desired that are as tightly spaced and as frequently recorded as economically feasible. However, the monitoring equipment should be mobile enough so that it can be moved as conditions change or as analyzed information indicates a need for information from different locations.

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Support of research into public health effects of air pollution; pollutant transport, transformation, and fate; and pollutant formation are also frequent needs of monitoring for which specific monitoring and site requirements may exist.

605.1.2 Previous and Existing Monitoring

Monitoring data is often available from previous monitoring efforts which may now be closed. The previous monitoring may have been short term or special study projects. In addition, there may also be data from existing monitoring stations in the area which provide a partial picture of the ambient concentrations for which a more extensive monitoring network is to be established. These available data can provide at least a partial picture of the conditions the network will monitor. From this information, the locations where the network stations are needed can be determined.

605.2 MINIMUM NETWORK REQUIREMENTS

In order to provide at least a minimum level of data return and quality a network of monitoring stations with a minimum number of stations in specifically targeted areas meeting specified objectives and general criteria is required. The requirements for these stations will vary depending upon the nature and goals of the network. Additional information is contained in Section 304 of this manual.

605.2.1 SLAMS Networks

There are no criteria for determining the total number of stations in a SLAMS network, except for a minimum number of lead SLAMS. The optimum size of a particular SLAMS network involves trade-offs between the data needs and available physical and fiscal resources. This optimum can be established during the network design process.

As a minimum, there must be at least two lead SLAMS in an urbanized area greater than 500,000 persons. Also, there must be at least two lead monitoring stations in areas that have exceeded the NAAQS in the past eight quarters.

The SLAMS monitoring stations must be located to meet at least four basic monitoring objectives:

- Highest concentrations expected in the area

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- Representative concentration in an area of high population density
- Impact of significant sources on ambient concentrations
- General background concentrations

Of these objectives, the most important to measure at if resources do not allow monitoring at four types of sites are the first two - highest concentrations and high population exposure.

The concept of spatial scale of representativeness helps clarify the link between the monitoring objectives and the physical location of the monitoring station. The goal in siting a monitoring station is to match the spatial scale representativeness of monitoring with the objective of the station or specific monitor. In cases, monitors of different scales can be located at the same monitoring station. The spatial scale of representativeness is described in terms of the physical dimensions of the air parcel monitored in which the pollutant concentrations are reasonably similar. These scales are:

- Microscale - several meters up to about 100 meters
- Middle Scale - 100 meters up to 500 meters
- Neighborhood Scale - 0.5 km up to 4.0 km
- Urban Scale - 4 km up to 50 km
- Regional Scale - tens of kilometers up to hundreds of kilometers
- National Scale - on a scale of thousands of kilometers
- Global Scale - generally mixed on continental to worldwide scale

Additional information about spatial scales of monitoring is contained in Section 603 of this manual.

The spatial and physical scales of monitoring, intended objectives, and properties and sources of the pollutants being monitored must be integrated when locating a monitoring site (Table 605.1). For example, CO concentration typically peak near roadways and decrease rapidly with distance from the street. In

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this case a microscale station is called for by the objective of monitoring the highest concentrations and the proximity of the concentration peak the of roadway. Many pedestrians may also be exposed on sidewalks beside the roadway. To determine CO concentrations that are representative of a larger area (for example: concentrations well mixed over an area the size of a typical housing tract) the station siting should meet the neighborhood scale criteria.

When monitoring secondary pollutants, such as ozone, transport, reactions rates, as well as precursor sources must be taken into account when deciding the scale and location of the monitoring stations.

Open path analyzers can often be used effectively to provide monitoring on neighborhood and larger scales. The inherent areal coverage of the path averaging beam lends itself to larger areawide averages. The monitoring path lengths need to be commensurate with the intended scale of representativeness and located carefully with respect to local sources or potential obstructions.

605.2.2 NAMS Networks

NAMS monitors are a subset of the SLAMS monitors, selected with an emphasis on urban and multisource areas. The primary objective of the

Table 605.1 Relationship of Monitoring Objective and Scale of Representativeness

| Monitoring Objective | Appropriate Siting Scales |
|-----------------------|--|
| Highest Concentration | Micro, Middle, Neighborhood, (sometimes Urban) |
| Population | Neighborhood, Urban |
| Source Impact | Micro, middle, neighborhood |
| General/Background | Neighborhood, Regional |

Table 605.2 Scale of NAMS Stations

| Category | Pollutant | Scale |
|--------------|--|------------------------|
| Category (a) | CO | Microscale |
| | Lead | Micro- or Middle Scale |
| | PM ₁₀ | Micro- or Middle Scale |
| | SO ₂ | Neighborhood Scale |
| | NO ₂ | Neighborhood Scale |
| | Ozone | Urban Scale |
| Category (b) | CO, Lead, PM ₁₀ , SO ₂ , Ozone | Neighborhood Scale |
| | NO ₂ | Urban Scale |

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NAMS is to monitor in areas where the pollutant concentration and population exposure are expected to be greatest, consistent with the averaging time of the NAAQS. The NAMS fall into two categories whose monitoring scale should be consistent with the purpose of the station (Table 605.2):

- Category (a): Stations located in area(s) of expected maximum concentrations.
- Category (b): Stations which combine poor air quality with high population exposure, but are not necessarily located in areas of the expected maximum pollutant concentrations. Category (b) monitors would generally represent larger spatial scales than Category (a) monitors.

For each urban area where NAMS are required, both categories of monitoring must be established. In the case of SO₂ and TSP, if only one NAMS is needed, then Category (a) must be used. The analysis of NAMS data must consider the distinction between the category types as appropriate.

The number of monitoring stations in an urban area depends on the population of the area and the concentration of the pollutant (Table 605.3).

605.2.3 PAMS Networks

The PAMS network is based on selection of an array of monitoring locations relative to ozone precursor source areas and the predominant wind direction associated with high ozone events. Each location in the array is associated with a specific objective: characterization of precursor emissions (total and speciated VOC and oxides of nitrogen), transport of precursor compounds into and out of

Table 605.3 NAMS Station Number Criteria

| Pollutant | Population Category | Approximate Number of Stations per Area | | | |
|--|---------------------|---|--------------------|----------------------|-------------------|
| | | | High Concentration | Medium Concentration | Low Concentration |
| CO | >500,000 | ≥2 | NA | NA | NA |
| Pb | >500,000 | ≥2 | NA | NA | NA |
| NO ₂ | >1,000,000 | ≥2 | NA | NA | NA |
| Ozone | >200,000 | ≥2 | NA | NA | NA |
| PM ₁₀ and PM _{2.5} | >1,000,000 | -- | 6 - 10 | 4 - 8 | 2 - 4 |
| | 500,000 - 1,000,000 | -- | 4 - 8 | 2 - 4 | 1 - 2 |
| | 650,000 - 500,000 | -- | 3 - 4 | 1 - 2 | 0 - 1 |
| | 100,000 - 500,000 | -- | 1 - 2 | 0 - 1 | 0 |

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the monitored urban area, transport of ozone into and out of the monitored urban area. The speciated VOC also forms an initial urban toxic air pollutant database.

A set of up to five stations makes up the PAMS array required in an affected nonattainment area. Specific monitoring objectives are associated with each station in the array using four distinct site types:

Type 1 - Sites that monitor upwind background and transported ozone and precursor concentrations entering the subject area. Type 1 sites are located in the predominant morning upwind direction from the local area of maximum ozone precursor emissions during the ozone season at a distance that allows the station to be classified as an urban scale monitoring station. Data from Type 1 stations is used principally for:

- Future development and evaluation of control strategies;
- Identification of incoming pollutants;
- Corroboration of NO_x and VOC emission inventories;
- Establishment of boundary conditions for future photochemical grid modeling and mid-course control strategy changes; and
- Development of incoming pollutant trends

Type 2 - Sites located immediately downwind (in the most common wind direction) of the area of maximum precursor emissions. These sites are established to monitor the magnitude and type of precursor emissions in the area of the expected impact of the maximum precursor emissions. These stations are typically placed near the downwind boundary of the central business district and situated such that they meet the requirements for neighborhood scale monitoring. Depending on the size of the area, a second Type 2 station may be needed. If needed, the second Type 2 station should be placed in the second most predominant morning wind direction. Data from Type 2 monitoring stations is used for:

- Development and evaluation of imminent and future control strategies;
- Corroboration of NO_x and VOC emission inventories;

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- Augmentation of RFP tracking;
- Verification of photochemical grid model performance;
- Characterization of ozone and toxic air pollutant exposures;
- Development of pollutant trends, particularly toxic air pollutants and annual ambient speciated VOC trends to compare with trends in annual VOC emission estimates; and
- Determination of attainment with the NAAQS for NO₂ and ozone.

Type 3 - Sites located downwind from the area of maximum precursor emissions. Type 3 stations are intended to monitor maximum ozone concentrations and are typically 10 to 30 miles downwind from the fringe of the urban area. The downwind direction should be determined from historical wind data of the afternoon winds occurring during the period of 1:00 pm to 4:00 pm on high ozone days (or days of potentially high ozone). These stations should be located so that they satisfy the siting requirements of urban scale monitoring stations. Data from Type 3 PAMS monitoring stations is used for:

- Determination of attainment with the NAAQS for ozone;
- Evaluation of future photochemical grid modeling applications;
- Future development and evaluation of control strategies;
- Development of pollutant trends; and
- Characterization of ozone pollutant exposures.

Type 4 - These sites are established to characterize the extreme downwind transported ozone and precursor concentrations exiting the study area. These stations will identify those areas which are potentially contributing to overwhelming transport in other areas. Type 4 sites are located in the predominant afternoon downwind direction, as determined for a Type 3 site and are located such that they satisfy the siting requirements of an urban scale monitoring station. Data from these monitoring stations is used for:

- Development and evaluation of ozone control strategies;

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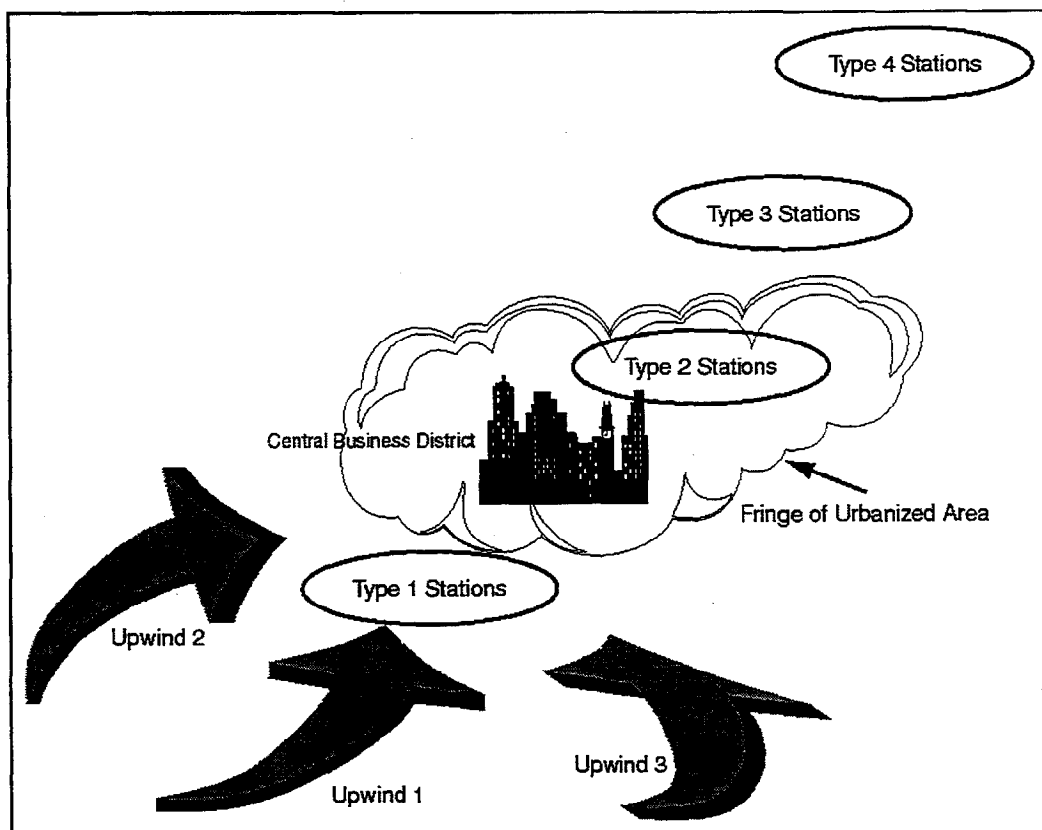


Figure 605.1 Layout of an Isolated Area PAMS Network.
Upwind 1 and 2 Represent the First and Second Most Predominant High Ozone Day Morning Wind Directions. Upwind 3 Represents the High Ozone Day Afternoon Wind Direction.

- Identification of emission and photochemical products leaving the area;
- Establishment of boundary conditions for photochemical grid modeling;
- Development of pollutant trends;
- Background and upwind information for other downwind areas; and
- Evaluation of photochemical grid model performance.

The PAMS monitoring stations may be arrayed around a single urban area (Figure 605.1) or multiple urban areas (Figure 605.2). When arrayed around multiple urban areas, the monitoring stations may function as more than one

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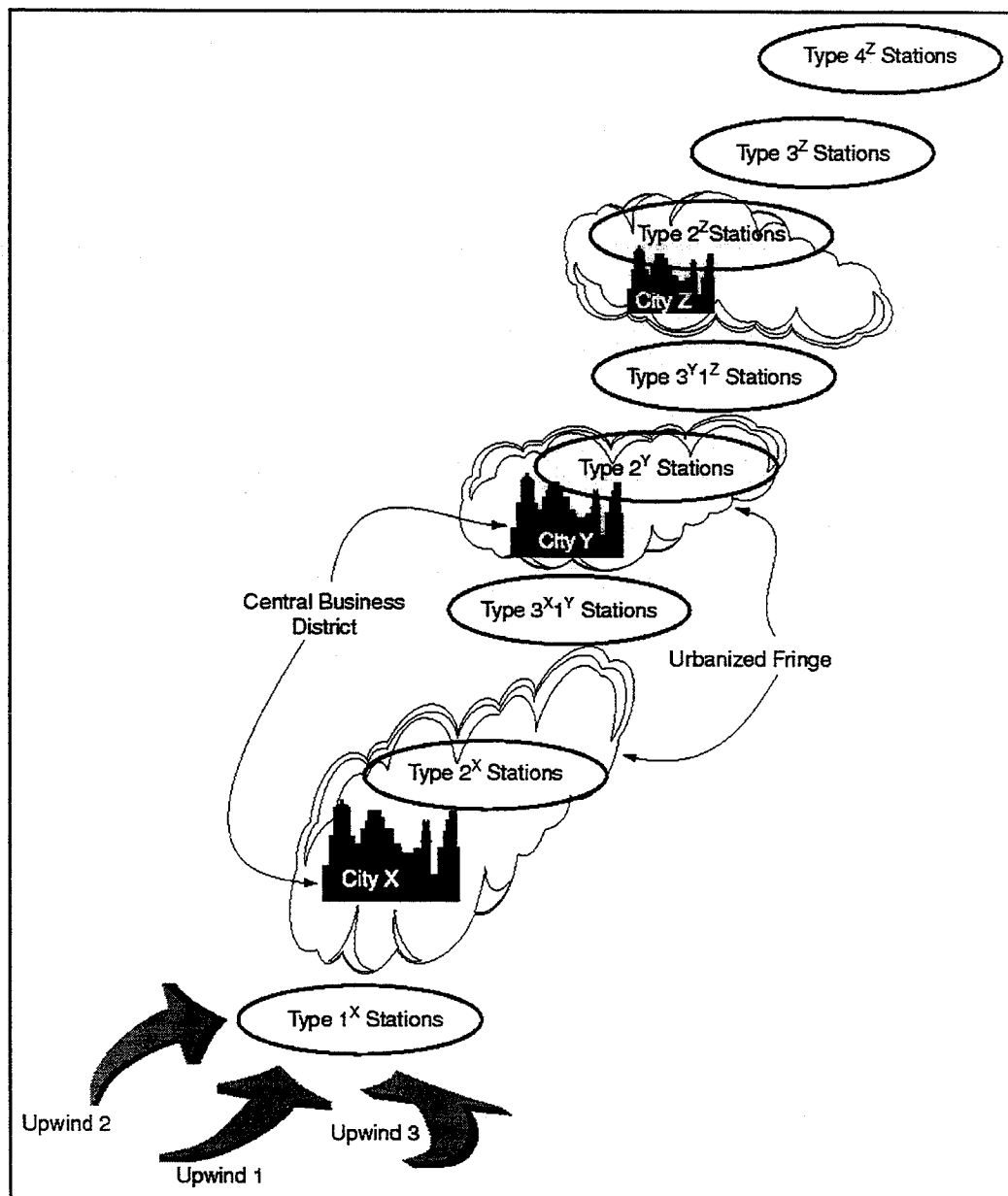


Figure 605.2 Layout of Multi-Area and Transport Area PAMS Network.

Upwind 1 and 2 Represent the First and Second Most Predominant High Ozone Day Morning Wind Directions. Upwind 3 Represents the High Ozone Day Afternoon Wind Direction. Superscripts Refer to the Type and City a Monitoring Station Pertains to (i.e. Type 3^{X1^Y} Stations Means the Station Serves as a Type 3 Station for City X and a Type 1 Station for City Y).

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type of station. For example: a station may serve as a Type 3 (downwind) station for one urban area and as a Type 1 (upwind) station for an urban area downwind of the first area.

Since PAMS is oriented toward monitoring of ozone and its precursors, year-round sampling is not necessary. Monitoring for precursor substances must be conducted during June through August; however monitoring throughout the entire ozone season is preferred. The minimum PAMS ozone monitoring must adhere to the SLAMS ozone season. The SLAMS ozone season (40CFR58 Appendix D, Section 2.5) lasts from a few months in summer to year-round depending on the state.

While ozone and NO_x monitoring should be continuous, speciated VOC and carbonyl sampling consists of 3 hour and 24 hour

Table 605.4 PAMS Network Sampling Frequency Categories

| Frequency Category | Three Hour Samples | | 24 Hour Samples | |
|--------------------|--------------------|--|-----------------|--|
| | Number | Frequency | Number | Frequency |
| A | 8 | Every third Day During the Monitoring Period | 1 | Every Sixth Day During the Monitoring Period |
| B | 8 | Every Day During the Monitoring Period | 1 | Every Sixth Day, Year Round |
| C | 8 | Five Peak Ozone Days Plus the Day Before | 1 | Every Sixth Day During the Monitoring Period |
| | 8 | Every Sixth Day During the Monitoring Period | | |
| D | 8 | Every Third Day During the Monitoring Period | NA | |
| E | 8 | Every Day During the Monitoring Period | NA | |
| F | 8 | Five Peak Ozone Days Plus the Day Before | NA | |
| | 8 | Every Sixth Day During the Monitoring Period | | |

Table 605.5 PAMS Network Minimum Monitoring Network Requirements

| Population of MSA/CMSA or Nonattainment Area (whichever is larger) | Required Site Type | Minimum Speciated VOC Sampling Frequency | Minimum Carbonyl Sampling Frequency |
|--|--------------------|--|-------------------------------------|
| Less Than 0.5 Million | Type 1 | A or C | |
| | Type 2 | A or C | D or F |
| 0.5 to 1.0 Million | Type 1 | A or C | |
| | Type 2 | B | E |
| | Type 3 | A or C | |
| 1.0 to 2.0 Million | Type 1 | A or C | |
| | Type 2 | B | E |
| | Type 2 | B | E |
| | Type 3 | A or C | |
| More Than 2.0 Million | Type 1 | A or C | |
| | Type 2 | B | E |
| | Type 2 | B | E |
| | Type 3 | A or C | |
| | Type 4 | A or C | |

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samples. The number and frequency of VOC and carbonyl samples depends on the size of the monitored area (Table 605.4 and Table 605.5).

The minimum required number and type of PAMS monitoring sites and sampling requirements are based on the population of the urban area or nonattainment area (whichever is larger). Often for the network to adequately characterize the ambient air quality of an urban or nonattainment area, it must extend beyond the boundary of the area.

Various sampling requirements pertain to areas of increasing size (Table 605.5) to accommodate the impact of transport on the smaller urban areas, to account for the spatial variations inherent in large areas, to satisfy the differing data needs of large versus small areas due to the intractability of the ozone nonattainment problem, and to recognize the potential economic impact of implementation of PAMS on state and local budgets.

Frequency categories C and F require sampling on the day of peak ozone concentration and the previous day. This requires the development of a means of forecasting those peak days. The scheme for forecasting the peak ozone days should be included as part of the PAMS plan submitted for approval and should be reviewed during each required annual review of the SLAMS network.

In order to support the PAMS monitoring objectives associated with the need for the various air quality analyses, model inputs, and model performance evaluations, meteorological monitoring is required at each PAMS site. Meteorological monitoring must include wind measurements at 10 meters above the ground and upper air meteorological monitoring. The upper air monitoring site may be located separately from the Type 1 through 4 sites, but must be representative of the upper air data in the nonattainment area.

605.2.4 PSD Networks

Under PSD the construction of certain new major stationary sources and major modifications are subject to a preconstruction review which includes an ambient air quality analysis and may require postconstruction ambient monitoring. If suitable air quality data exists, that data may be used for the preconstruction analysis. If it doesn't exist, ambient monitoring may be required before the construction permit may be issued.

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For SO₂, CO, and NO₂ continuous air quality monitoring data must, in general, be used to establish the preconstruction ambient air quality in the vicinity of the proposed facility. For VOC, continuous ozone monitoring data must be used; and the 24-hour manual method used for PM₁₀ and lead. However, no preconstruction monitoring data will generally be required if the ambient air quality concentrations before construction are less than the significant monitoring concentrations (Table 605.6). Below the significant monitoring concentration levels measurement errors dominate the values, making their use questionable.

Cases where the projected impact of the source or modification is less than the significant monitoring concentration are also exempt from the preconstruction monitoring requirement, consistent with the de minimis concept. The exception to the de minimis exemption occurs when a proposed source of modification would adversely impact on a Class I area or would pose a threat to the remaining allowable increment or NAAQS.

The EPA has discretion in requiring postconstruction monitoring. In most cases they do not require monitoring. However, if there are valid reasons for the data, postconstruction monitoring may be required. Generally, postconstruction

Table 605.6 Significant Monitoring Concentrations

| Pollutant | Air Quality Concentration (µg/m ³) and Averaging Time |
|---|---|
| Carbon Monoxide | 575 (8 Hour) |
| Nitrogen Dioxide | 14 (Annual) |
| Sulfur Dioxide | 13 (24 Hour) |
| Particulate Matter (TSP) | 10 (24 Hour) |
| Particulate Matter (PM ₁₀) | 10 (24 Hour) |
| Ozone | (a) |
| Lead | 0.1 (3 Month) |
| Asbestos | (b) |
| Beryllium | 0.001 (24 Hour) |
| Mercury | 0.25 (24 Hour) |
| Vinyl Chloride | 15 (24 Hour) |
| Fluorides | 0.25 (24 Hour) |
| Sulfuric Acid Mist | (b) |
| Total Reduced Sulfur (Including H ₂ S) | 10 (1 hour) |
| Reduced Sulfur (Including H ₂ S) | 10 (1 hour) |
| Hydrogen Sulfide | 0.2 (1 Hour) |

a. No Specific air quality concentration for ozone is prescribed. Exemptions are granted when a source's VOC emissions are <100 tons per year.

b. No acceptable monitoring techniques are available at their time. Therefore, monitoring is not required until acceptable techniques are available.

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monitoring is only required of large sources or sources whose impact may threaten the NAAQS or the PSD increment. Postconstruction monitoring may also be required if such factors as complex terrain, fugitive emissions, and other uncertainties in source or emission characteristics result in significant uncertainties about the projected impact of the new source or modification. In this case the postconstruction monitoring is needed to assess the emission model performance.

Pre- and postconstruction monitoring may also be required of sources of noncriteria pollutants; however, modeling is the preferred analysis tool for noncriteria pollutants.

605.2.5 SPMS Networks

Special purpose monitoring stations (SPMS) is a generic term used for all monitors other than SLAMS, NAMS, PAMS, and PSD monitors included in an agency's monitoring plan or for monitors used in special studies whose data are reported to the EPA. Special purpose monitoring stations are used as a tool to supplement the ambient air monitoring network to obtain information on where to locate permanent monitoring stations, to provide additional data in support of pollutant formation and transport analyses, or to assess air quality in a particular location. Industries often operate special purpose monitoring in support of the PSD program and to satisfy their own information needs on air quality around their facilities. Special purpose monitoring studies vary in duration from temporary sites needed only during a portion of the year to long-term air pollution studies over large areas. Examples of long-term SPMS are the CASTNet (Clean Air Status and Trends Network) and IMPROVE (Interagency Monitoring of Protected Visual Environments).

Special purpose monitoring fills a need to look beyond the basic SLAMS network and provides flexibility to a monitoring program. An SPMS is not required to use reference or equivalent methods, nor is the data required to be submitted to the EPA. However, an SPMS monitor from which the state intends to use the data as part of demonstration of attainment or nonattainment, or in computing a design value for control purposes of the NAAQS, must meet the requirements for SLAMS. For use in any other SIP-related purposes, although not required to meet the SLAMS requirements, the SPMS must be operated in accordance with a monitoring schedule, methodology, quality assurance procedures, and probe or instrument siting specifications approved by the EPA Regional Administrator.

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605.3 AVAILABLE MONITORING SITES

One of the most difficult parts of establishing an air monitoring network is finding and securing an appropriate site at which the station can be located. The site for the station must be in the proper area and a long-term agreement or lease must be acceptable to the property owner.

605.3.1 Locations

A number of different types of locations are utilized for monitoring stations. The specific type facility used for the station depends largely on the area in which the station is to be located and the purpose and objective of the program. Most commonly, the stations are located in leased commercial space (typically in strip shopping center storefronts), public buildings (fire stations, police stations, county offices, etc.), or freestanding trailers. In rural and remote areas the freestanding trailers are generally used since there are few fixed building options available and trailers can be located wherever necessary. In urban and suburban areas, public buildings and leased commercial space is commonly used. Unless the station is for short-term special purpose monitoring or research, long-term stability of the monitoring site is important to provide a consistent dataset.

Unless the station is to include only samplers such as the PM_{10} that require only exterior facilities, access to both the roof and an interior instrument room is required. This leads to one of the frequent objections by potential landlords: the roof of most buildings is not designed for frequent traffic. It is usually a good idea to build a wooden walkway to the samplers to prevent walking directly on the roof surface.

Samplers such as the PM_{10} that are freestanding are typically placed on the roof of the monitoring station. Servicing requires that the station technician climbs to the roof at least once a week to change filters on the instrument.

Most other monitoring instruments require that an inlet penetrate from above the roof into the instrument room. Many potential landlord are leery of having a hole made in their roof for this tubing.

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605.3.2 Costs

The costs of establishing and maintaining an air monitoring station are quite substantial. Initially, there are the costs of the equipment and facility preparation. The monitors for the station cost between \$5,000 and \$20,000, depending on the pollutant being monitored and the brand of instrument purchased. With the costs of the trailer or facility renovations, a monitoring station can easily exceed \$100,000 to establish.

The most important costs of monitoring; however, are the long-term costs. For each monitoring instrument installed, an adequate supply of spare parts must be on hand for immediate repairs. If parts must be ordered, the downtime for the instrument may exceed the allowed downtime and cause an insufficient data return for the day, month, quarter, or even year, voiding all other data gathered for that time. Allowance in the budget must also be made for other maintenance and calibration costs and expendable items such as calibration gases, strip chart paper, pens, etc. The greatest expense; however, is in personnel. As a rule of thumb, a technician can maintain one main station and several satellite stations.

606 REFERENCES

1. *Code of Federal Regulations, Title 40, Part 58*, 1998, U.S. Government Printing Office.
2. U.S.EPA, 1994, *Photochemical Assessment Monitoring Stations Implementation Manual*, EPA-454/B-93-051.
3. U.S.EPA, 1998, *Guideline on Ozone Monitoring Site Selection*, EPA-454/R-98-002.
4. U.S.EPA, 1987, *Network Design and Optimum Site Exposure Criteria for Particulate Matter*, EPA-450/4-87-009.
5. Federal Register, 20 Jan 1999, 64FR3030.
6. U.S.EPA, *Summary Fact Sheets*.
7. Federal Register, 18 July 1997, 62FR138.

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8. Oikawa, Susumu and Yan Meng, 1997, A Field Study of Diffusion Around a Model Cube in a Suburban Area, *Boundary Layer Meteorology*, 84:339-410.
9. Irvine, M.R., B.A. Gardiner, and M.K. Hill, The Evolution of Turbulence Across a Forest Edge, *Boundary Layer Meteorology*, 84:467-496.
10. Harrison, Paul R., 1973, Considerations for Siting Air Quality Monitors in Urban Areas, *Proceedings of the Air Pollution Control Association*.
11. Falke, Stefen R. and Rudolf B. Husar, 1997, Declustering in the Spatial Interpolation of Air Quality Data, *Proceeding of the Air and Waste Management Association*.

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Data collected for ambient air quality monitoring programs are used for various and often specific decision making processes. These decisions may have significant environmental and economic impacts; therefore, they require high quality and timely data. The users of the data must feel confident that the data used to make their decisions are of adequate quality. The data are never error free and always contain some level of uncertainty, but careful and thorough data handling, documentation, and quality assurance programs will minimize errors and uncertainties. Through a predetermined data quality objectives program, the level of uncertainty can be specified such that the required confidence and delivery timeliness can be assured. The data handling phase reflects the acquisition, review, and archiving of the data generated by the monitoring stations.¹

701 DATA ACQUISITION

The task of data acquisition involves retrieving the ambient air quality data from instrument readouts, data loggers, strip charts, microprocessor based data acquisition systems, or laboratory data reports and transmitting the data to the appropriate receiving agency office.

Data acquisition from continuous monitors is generally composed of either strip chart recorders or electronic data acquisition and transmission. Increasingly, data is directly linked from the instrument to the agency office. This may be taken an additional step and real-time data can be accessed via the internet. Internet access allows a convenient means of data transmission and allows anyone to see the real-time air quality. Any user of real-time data; however, must be forewarned that the data has not been reviewed and may be adjusted or voided if quality assurance review indicates it does not meet the data quality objectives.

The nature of the manual sampling methods, such as PM_{10} and $PM_{2.5}$, require some data to be recorded in the field (start time, stop time, flow rates, etc.) and some data to come from the laboratory (pre- and post-weights, etc.). Therefore, real-time data is not feasible.

Most continuous air monitoring systems include a strip chart for a permanent hard copy record. The strip chart also provides a good graphical tool for an inspector to examine the operation of the station. Reflecting this aspect, most computer data acquisition software allows the data to be displayed as an imitation of a strip chart. A station operator or inspector can easily scan a strip chart output (or computer stripchart image) for gross errors and failures and to observe

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the occurrence and approximate values for routine zero and span checks. The strip chart also can be scanned for episodes meeting or exceeding the state and federal air quality standards. Accurate values for the ambient pollutant concentrations and for the zero and span checks should be obtained from the data logger and/or computer data acquisition system.

Most monitoring stations use automated data acquisition processes for their primary data acquisition. In these processes the conversion and calibration factors and equations are incorporated into the acquisition procedure and are not directly visible.

The automatic application of the conversions and calibrations reduces the number of calculations and transcriptions of the data and so reduces the chances for errors. However, as part of a review of a monitoring station, an inspector should have the station operator query the data logger and/or computer to print or display the factors and equations that are being used to be sure that current and accurate calculations are being made.

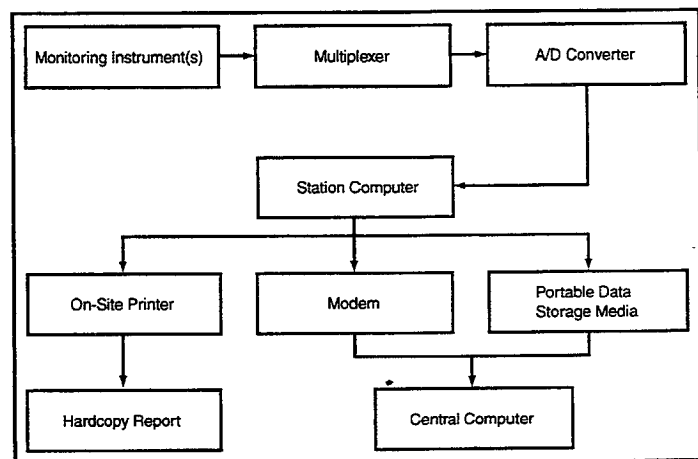


Figure 701.1 Example Data Acquisition System Flow Diagram

In addition to the final calculated result, the raw input data directly from the analyzer (after being digitized if the analyzer output is analog) should be stored. If a question ever occurs relative to the conversion or calibration of the instrument, this raw data can be retrieved and reviewed.

Figure 701.1 shows an example basic automated data acquisition process. In summary:

- The multiplexer sequentially poles the instruments at the station and forwards the voltages to the analog-to-digital (A/D) converter. Using a multiplexer allows the voltage outputs from several instruments to be connected to a

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single data acquisition system. The multiplexer is not needed if there is only one instrument at the station.

- The output of most analyzers is a DC voltage in the 0-1 or 0-5 volt range. The A/D converter converts the analog signal to a digital one that the computer can process.
- The A/D sends the digitized data to the computer which stores the raw data, performs the necessary calculations, and displays the values. In the calculations the individual data points are accreted into time averages, which are then also displayed.
- On a routine basis (for example, daily) the data may be printed at the monitoring station and the hard copy archived. This creates a back-up of the electronically based data. Notes can also be made on the hard copy report to document regional and local factors (i.e. construction, etc.) that may effect the data quality.
- Also on a routine schedule, the data should be stored to a removable media (computer disc, tape, etc.) for archiving and forwarding to a central computer facility or to the end user.
- As an alternative to sending a disc or tape to the central computer or end user, the data may be accessed by a remote computer via a station modem and directly transferred.

Having a modem as part of the monitoring station simplifies transfer of data to the central computer. It also allows pollution forecasters to check the real-time pollutant concentrations and instrument technicians to diagnose malfunctions.

702 DATA REVIEW

On occasion special events and conditions can cause an exceedance of the NAAQS. Most commonly these events cause exceedance of the particulate matter standards; although all criteria pollutants can be exceeded. When a special event or condition occurs the data submitted to the EPA AIRS database must be marked with a flag noting that the additional information is available or that special treatment and consideration for waiver of the NAAQS is requested.

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There are a number of situations in which a data flag may be applied to request regulatory relief or alert the data user to a special event or condition. These events and conditions are extensively discussed in Section 301.4 of this manual.

Data review is closely associated with data acquisition. It is the first step in the quality assurance process. The station operator has responsibility for the first level of data review. He or she should review the strip chart output (or computer data file) daily to check for nightly calibration or zero and span checks and for exceedances of the ambient standards.

The operator's initial check of the data is important since he/she should be the most familiar with the functioning of the instruments and the potential sources of interferences in the vicinity of the station. The operator should also be most familiar with the expected concentrations and diurnal patterns. Therefore, he/she is the most likely person to quickly identify errors and malfunctions of the equipment and unusual pollution events. The review by the station operator should include:

- Review of the calibration information, the hourly data, any flags that could effect the data, and recording any information on the daily summaries that might be vital to proper review of the data.
- The station operator should also periodically send the strip charts, daily summaries, monthly maintenance sheets, and site logs to the air monitoring headquarters for second level review.
- The data processing staff should review all hand reduced data, calibrations, precision data, station notes, and monthly maintenance sheets. A percentage of the calibration and strip chart data should be checked against the electronic data; if significant differences are noted the proper corrective action should be determined and carried out.

As has been noted, there will be circumstances in which erroneous data is collected. The erroneous data may be identified during the data review or as a result of an audit (see Chapter 800). When this happens the data set needs to be corrected or the erroneous data deleted. It is better to have periods of missing data than erroneous data.

The best option when erroneous data has been identified is to correct the data. If an exact time period and the cause of the errors can be isolated and quantified a

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correction factor may be able to be calculated. In which case the factor may be used to correct the data. A preferable procedure would be to apply a revised calculation to the raw data stored during the data acquisition.

If an exact time period or cause cannot be determined, or a correction factor cannot be calculated, then the data in question should be deleted from the database.

703 AEROMETRIC INFORMATION RETRIEVAL SYSTEM

The Aerometric Information Retrieval System (AIRS) is a computer-based repository of information about airborne pollution in the United States and various World Health Organization (WHO) member countries.² The system is administered by the U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards (OAQPS), Information Transfer and Program Integration Division (ITPID), located in Research Triangle Park, North Carolina. AIRS is installed on the IBM computer system at the EPA's National Computer Center (NCC) in Research Triangle Park, North Carolina. Any organization or individual with access to the EPA computer system may use AIRS to retrieve air pollution data. The AIRS TTN web site (<http://www.epa.gov/ttn/airs>) is designed to provide technical information about the AIRS data management system primarily to AIRS users (state and local agency management, EPA Regional Offices, consultants, and environmental groups.)

703.1 AIRS SECTION OF EPA'S TECHNOLOGY TRANSFER NETWORK (TTN)

The Technology Transfer Network is a group of Websites that provide technical and regulatory information about air pollution. The TTN has information ranging from emissions test methods to regulatory air pollution models. There are tools for estimating air pollutant emissions, computer code for regulatory air models, Title by Title summaries of the Clean Air Act, and discussion forums where you can ask questions and share ideas. The TTN's primary audience is environmental professionals, but the Websites are open to anyone who wishes to visit them. The TTN/AIRS Technical Website has been designed for use by State and Local Air Pollution Control Program professionals to assist them with their day to day work of collecting, validating and storing air pollution data in the AIRS Database.

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703.2 PURPOSE OF AIRS

AIRS contains all air quality, emissions, compliance, and enforcement information that OAQPS and state agencies need to carry out their respective programs for improving and maintaining air quality. Reporting capabilities allow states to access and use their data. It eliminates the need for individual states to maintain their own databases of air pollution information and to reformat or reorganize data for submission to the EPA's database. AIRS provides standard information requirements and information handling procedures, which enables OAQPS to compare and to use data from different states.

703.3 ACCESS TO THE AIRS DATABASE

Much of the data stored in AIRS is available through the TTN/AIRS internet web site. For more extensive access to the data (i.e. for full access to the data and to upload or modify data) an account on the EPA computer hosting the AIRS database is required. Contact the U.S.EPA for such an account.

703.4 AIRS SUBSYSTEMS AND APPLICATIONS

The AIRS database consists of several parts ranging from the ambient pollutant concentration data and emission source data to the software and procedures for generating reports and maps from the data.

703.4.1 Air Quality Subsystem (AQS)

The AIRS Air Quality Subsystem (AQS) contains measurements of ambient concentrations of air pollutants and associated meteorological data. The subsystem also contains descriptive information about each monitoring station, including its geographic location and who operates it. The data is collected by thousands of monitoring stations operated by EPA, national, state and local agencies. The EPA uses this data to assess the overall status of the nation's air quality and to prepare reports to Congress as mandated by the Clean Air Act. The EPA also uses the data to identify areas where improvements in air quality are needed.

703.4.2 AIRS Facility Subsystem (AFS)

The AFS contains both emissions and compliance data on air pollution point sources regulated by the U.S.EPA and/or state and local air regulatory agencies.

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AFS contains data on industrial plants and their components: stacks, the points at which emissions are introduced into the atmosphere; points, the emission point or process within a plant that produces the pollutant emissions; and segments, which are components of the processes that produce emissions. Compliance data is maintained at the plant and point levels, tracking classification status, inspections, and compliance actions. AFS also includes data for management of operating permit applications and renewals.

703.4.3 Geographic, Common, and Maintenance Subsystem (GCS)

The GCS is a repository of reference data shared by the AQS, AFS, and AMS subsystems. The data includes codes and code descriptions used to identify places, pollutants, and processes, geographic information, and values such as air quality standards and emission factors.

703.4.4 AIRS Graphics (AG)

The AG integrates data from multiple AIRS subsystems into maps and charts that enable users to identify patterns, trends, and anomalies in air pollution data. AIRS Graphics has interactive menus that make it easy to choose "graphical reports", and to select options that control their contents. AG software takes care of all the details and displays color graphics. You may then save the graph, request color prints, export the graph and/or data in PC format, and browse the data used to create the graph.

703.4.5 AIRS Executive (AE)

The AE section of AIRS is an IBM PC program that contains a select subset of data extracted from the AIRS database. Its user-friendly format guides you to air pollution information on ambient air and plant emissions sources.

703.4.6 AIRSData

The AIRSData section provides access from the Web to the same subset of AIRS data included in AIRS Executive. AIRSData has summaries of air monitoring data for the current and five prior years, the latest available estimates of air pollutant emissions from major point sources, the overall regulatory compliance status of those sources, and names of contacts in the EPA and state/local air pollution agencies. All these data pertain to the criteria pollutants (carbon monoxide, nitrogen dioxide, sulfur dioxide, ozone, particulate matter, lead).

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AIRSDATA includes data for the 50 States plus the District of Columbia, Puerto Rico, and Virgin Islands.

703.5 USES OF AIRS DATA

There are many uses of the AIRS data. Reports, data tables, and maps for ambient air quality, emission sources, and monitoring stations are readily generated for any one or more year(s). Some of the EPA's reports include:

Air Quality Trends Report: For the past 25 years, the EPA has evaluated the trends and status of our nation's air quality, and has presented the results of this evaluation in an annual publication known as the National Air Quality and Emissions Trends Report. The National Air Quality and Emissions Trends Report discusses the nation's progress in cleaning up air pollutants.

Emission Trends Report: This annual publication summarizes long-term trends in emissions of air pollutants and gives in-depth analysis of emissions for the current year.

The Green Book: This provides extensive information about nonattainment areas and National Ambient Air Quality Standards for the six criteria pollutants.

Airs Executive: The AIRS Executive is PC software that lets the user explore summaries of air pollution data for the United States and 50 nations. It includes ambient air quality summaries from monitoring sites, plus estimates of air pollutant emissions from large stationary sources in the United States.

The Blue Book: This web site presents a summary of the maintenance plan and contingency measures for each area that has been redesignated from ozone nonattainment to attainment for the 1-hour ozone standard as of September 30, 1997.

703.6 THE AIR QUALITY SUBSYSTEM (AQS)

The AQS contains measurement of ambient concentrations of air pollutants and associated meteorological data. The data are collected by thousands of monitoring stations operated by the EPA, national, state, and local agencies. The EPA uses this data to assess the overall status of the nation's air quality and to prepare reports to Congress as mandated by the Clean Air Act. The EPA also uses the data to identify areas where improvements in air quality are needed. Routines

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and procedures in the AIRSData subsystem can be used to generate reports from the AIRS data.

703.6.1 Types of Data in AQS

Several types of data are stored in the AIRS AQS databases. These data describe the monitoring sites, list the air quality data, and list the QA data.

Monitoring site descriptions provide information about the monitoring sites that provide data to AIRS. The information includes the site location (geographic coordinates, street address, city, county, state, AQCR, etc.), site operational dates, the organization responsible for monitor operation, and many other items. State and local agencies provide site information to AIRS.

Raw data are the individual values of pollutant concentrations or meteorological conditions measured at the monitoring sites and supplied to AIRS by the national, state, and local agencies that operate the monitors. Most raw data values are either 1-hour averages of continuously-sampled pollutant concentrations, or 24-hour averages derived from discrete or intermittent samples.

Summary data are derived from raw data. They include annual and quarterly maximum, minimum, and average raw data values; total number of values reported; number of values exceeding national ambient air quality standards; and numerous other common statistical measures.

Precision and accuracy data (P-A) provide information regarding the precision and accuracy of air quality monitors. AIRS has P-A data for each individual monitor, and summaries for groups of monitors operated by each state or local reporting organization.

703.6.2 DATA INPUT AND UPDATE PROCEDURES

Most of the air quality and precision-accuracy data in AQS comes directly from the SLAMS and NAMS air monitoring networks, which are operated by state and local pollution control agencies. A small amount of raw data comes from monitors operated by the EPA or private sources. In addition, AQS includes air quality data submitted by about 45 World Health Organization (WHO) member nations.

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New air quality data is loaded into AQS and existing data is modified or deleted using transactions (Table 703.1).^{3,4} Depending on the information to be entered or updated, one of the transaction type databases (i.e. Basic Site Information [AA], Monitoring Objective Information [ME], etc.) is selected and the data entered. To complete data entry may require several transaction types (and data entry in the respective databases).

The first five fields in all transaction types is required basic identification information: transaction type (abbreviation of the transaction type table into which the data is to be entered); action code (enter "I" to insert a new record, "U" to update information, or "D" to delete information); state code; county code; and site ID. The remaining fields contain the specific information for the transaction entry, some of which are required and some optional.

For example: for the Monitor Type Information transaction (type MC) in addition to information in the five basic fields, information about the parameter (i.e. pollutant), POC (parameter occurrence code - a code used to distinguish between different monitors at one site that are measuring the same parameter), monitor type, date when monitoring began, and date when monitoring ended. In this transaction type all fields except the ending date are required to have valid entries.

Table 703.1 AIRS Transaction Types

| Transaction Types | | Number of Fields | Number of Delimiters |
|-------------------|------------------------------------|------------------|----------------------|
| AA | Basic site information | 42 | 41 |
| AB | Site street information | 12 | 11 |
| AC | Site open path information | 13 | 12 |
| MA | Basic monitor information | 28 | 27 |
| MB | Monitor sampling periods | 9 | 8 |
| MC | Monitor type information | 10 | 9 |
| MD | Monitor agency role | 11 | 10 |
| ME | Monitoring objective information | 11 | 10 |
| MF | Monitor sampling schedule | 22 | 21 |
| MG | Monitor street description | 9 | 8 |
| MH | Monitor obstruction information | 11 | 10 |
| MI | Monitor regulatory compliance | 10 | 9 |
| MJ | Monitor collection period | 11 | 10 |
| MK | Monitor minimum detectable | 14 | 13 |
| RC | Composite raw data | 25 | 24 |
| RD | Hourly, daily, sub-hourly raw data | 26 | 25 |
| RA | Accuracy data | 32 | 31 |
| RP | Precision data | 16 | 15 |
| RS | Annual summary data | 38 | 37 |

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An organization submitting air quality data to AQS creates a transaction file on the IBM computer system at the EPA's National Computer Center. The organization uses AQS software to load the transactions into a "screening file," check the validity of the transactions, and correct any errors found. A screening file is part of the AQS database, and is used to hold AQS transactions during validation. Each organization submitting data to AQS has one or more screening files for its exclusive use.

When the transactions in a screening file have passed validation checks, the organization submitting the data notifies the AIRS database administrator that the screening file is ready to be used for updating the AIRS database. The database administrator performs updates on a regular schedule (usually once per week) using all screening files that are ready at that time.

703.6.3 AQS DATA RETRIEVAL

Most of the air quality data in AIRS are available to any person or organization with legitimate access to the EPA National Computer Center. There is a small amount of private, or 'secured', data that is accessible only by the submitting organization. Secured data is primarily used for experimental monitoring methods and corporate monitors. There are three ways to retrieve air quality data from the AIRS database: Online Browse, Standard Batch Retrieval, and Ad hoc Batch Retrieval.⁵

The AQS Online Browse option displays data online. The criteria for data selection is specified and AIRS software retrieves and displays the data in formatted screens.

The AQS Standard Batch Retrieval option generates printed reports and/or data files. For standard batch retrieval criteria for data selection and sorting are selected and the options that affect report format and content are chosen. AIRS software automatically submits a batch job to produce the requested report and/or data file. Many report formats are available, and selection criteria are flexible enough to meet most information needs.

If the Standard Batch Retrieval and Online Browse facilities do not satisfy their requirements, experienced users can define supplemental reports via the AQS Ad Hoc Batch Retrieval option. In the ad hoc batch retrieval process the data fields used to select data and which fields are included in the report and/or output data

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file are selected. To do this, however, a thorough understanding of the database organization, and data field names is needed.

703.6.4 History of AQS

The AIRS Air Quality and Geo-Common Subsystems became operational in July 1987, culminating more than seven years of planning and development. EPA completed the feasibility study for a new air data system in September 1980.⁶ The AIRS Design Specifications manual, completed in January 1983, presented the overall plan for the system's organization and capabilities. During the next four years, contractors and EPA developed detailed specifications for two of the AIRS subsystems, wrote and tested the software to implement the specifications, and converted data in predecessor databases for loading into AIRS. In 1993, modifications were made to accommodate data submitted by countries spanning North and South America, Asia, Europe, Africa, and Australia.

The AIRS Air Quality Subsystem replaced SAROAD (Storage and Retrieval of Aerometric Data), which was implemented after Congress passed the Clean Air Act in 1963. SAROAD contained ambient air quality and meteorological data, including some data from the National Air Sampling Network. This network was established in 1957 as the first nationwide air monitoring system. Because data were absorbed into each succeeding system, some data in the Air Quality Subsystem date back to 1957.

The state pollution control agencies supplied most of the information in SAROAD. These agencies submitted raw data to the 10 EPA regional offices, which checked the data and corrected errors. EPA headquarters used validated data supplied by the regional offices to update the SAROAD data files. The Air Quality Data Handling System (AQDHS/II) was developed by the EPA and installed on the states' and EPA computer systems to assist the states with air quality data submission. The primary purpose of AQDHS/II was to convert the states' data into a standard format compatible with SAROAD. AQDHS/II also provided the states with minimal capabilities for maintaining their own pollution data systems.

SAROAD and AQDHS/II provided valuable data handling capabilities for many years, but using it required a lot of computer knowledge and experience. AIRS was designed to provide additional capabilities and to foster direct use by state and local agencies submitting the data. All functions are initiated with easy-to-

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use menus and data entry screens displayed on full-screen terminals. The EPA regional offices no longer need to be involved with routine data submission. The states submit their data directly to the Air Quality Subsystem, receive data validation reports, and correct errors online using a terminal. Data retrieval is an integral part of AIRS and is readily available to users. An array of standard reports is available, and the database management software provides the capability for user-developed reports. Standard report programs also can generate data files for use with statistics or graphics packages.

704 REFERENCES

- 1 U.S.EPA, 1994, *Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II: Ambient Air Specific Methods*, EPA/600R-94/038b.
2. U.S.EPA, 1999, *AIRS Basic Facts*, <http://www.epa.gov/airs/airs2.html>.
3. U.S.EPA, 2000, *AIRS User's Guide Volume AQ2*.
4. U.S.EPA, 1999, *Data Input Formats for the Re-engineered Air Quality system*.
5. U.S.EPA, 2000, *AIRS User's Guide Volume AQ4*.
6. U.S.EPA, 1999, *AQS - Air Quality Subsystem*, <http://www.epa.gov/airs/aqs.html>.

800 QUALITY ASSURANCE

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Quality control/quality assurance is the overall system of technical activities that measures the attributes and performance of a process, item, or service against a predefined set of standards to verify that the data meet the requirements of the end user. To assure the quality of data from air monitoring measurements, two distinct and interrelated functions must be performed. One function is the control of the measurement process through broad quality assurance activities, such as establishing policies and procedures, developing data quality objectives, assigning roles and responsibilities, conducting oversight and reviews, and implementing corrective actions. The other function is the control of the measurement process through the implementation of specific quality control procedures, such as audits, calibrations, checks, replicates, routine self-assessments, etc. In general, the greater the control of a given monitoring system, the better will be the resulting quality of the monitoring data. The results of quality assurance reviews and assessments indicate whether the control efforts are adequate or need to be improved. An ambient air monitoring quality assurance program generally consists of four parts: planning, implementation, assessments, and reports.

801 PLANNING

Air monitoring projects may be brilliantly conceived, however, without a well planned and organized quality assurance plan, the data will, at least on the surface, prove unreliable. Project success depends on the leadership and organizational skills of the project manager. The entire staff must know what needs to be done and how they fit into the "big picture" of the project.

A detailed air monitoring project description forms the basis for all other planning activities. Unless all six standard questions (who, what, when, where, why, and how) are addressed in the monitoring and QA plans, the project description is incomplete and subject to misinterpretation.¹ All six questions must be succinctly and completely answered:

- What is going to be done?
- Why is it necessary?
- Who will do it?
- How will it be accomplished?

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- Where will it be done?
- When will it be carried out?

An important part of quality assurance planning is to have written (and up to date) standard operating procedures (SOPs). Data collected using fully documented procedures have much higher credibility and defensibility. An SOP also will help assure that all procedures will be performed consistently by everyone at all times.

802 DATA QUALITY OBJECTIVES

It is important that the data returned by the ambient monitoring program meet specific constraints (commonly referred to as data quality objectives, DQOs) designed to assure that the level of uncertainty of the data meets the requirements of the user. There are serious political, economic, and health consequences of incorrect decisions based on biased data. Data biased high (Figure 802.1a) may cause an area to be declared nonattainment when it is actually in

attainment (a false positive); with the political and economic costs of implementing more stringent controls. Conversely, data biased low (Figure 802.1b) may cause an area to be wrongly declared attainment (a false negative); leading to the health costs of exposure to excessive levels of pollutants. While data meeting DQOs is not immune to false positive or false negative decisions, if the data meets the requirements the user knows the probability of such a false decision.

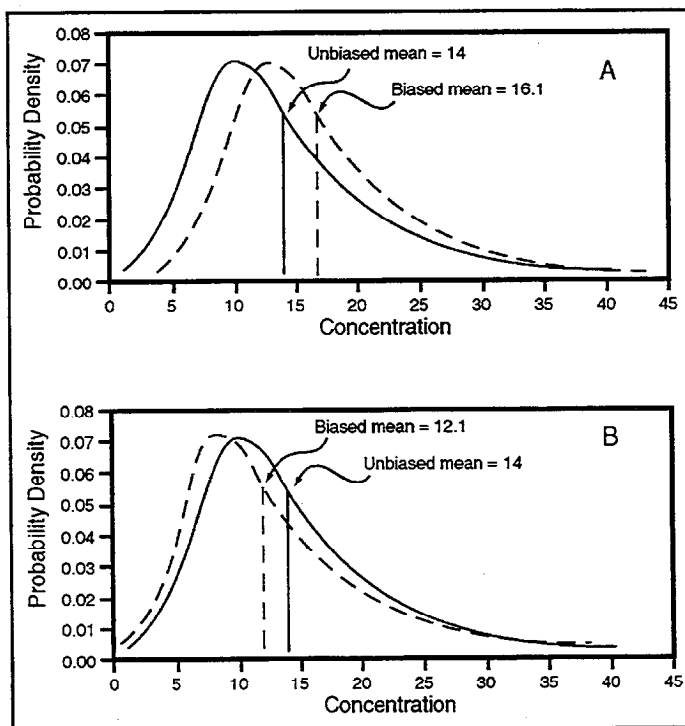


Figure 802.1 Effect of Bias on the Annual Average. A. Positive Bias, B. Negative Bias²

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In order to set probability limits on the decision errors, one needs to understand and control uncertainty. Uncertainty can be illustrated as:²

$$S_o^2 = S_p^2 + S_m^2$$

Where:

S_o = overall uncertainty

S_p = population uncertainty (spatial and temporal uncertainty)

S_m = measurement uncertainty (analyzer uncertainty)

The population uncertainty refers to the degree to which the sample is accurately and precisely collected from the air mass. The population uncertainty includes functions associated with the station siting and the temporal components of the sample. Assuring collection of representative samples depends on:

- Selecting a network size that is consistent with the monitoring objectives;
- Locating representative sampling sites;
- Determining constraints on the sampling sites imposed by meteorology, local topography, emission sources, and the physical configuration of the sampling site and documenting these; and
- Planning sampling schedules that are consistent with the monitoring objectives.

The measurement uncertainties are those associated with the sampling operation itself. These include uncertainties such as those of the field environment, the sample or substrate preparation, and laboratory measurements.

The overall accuracy (i.e. closeness to the 'truth') of a measurement is used in the CFR for ambient monitoring to mean the combination of precision (mutual agreement among individual measurements) and bias (systematic distortion of a measurement process which causes errors in one direction.) To provide information critical to the evaluation of the overall accuracy, both the precision and bias values should be reported (Figure 802.2).

A third quantity important to the quality of ambient air data is the detection limit for the analysis method. The detection limit provides a value of the lowest measurement that can be reliably discerned.

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802 DATA QUALITY ASSESSMENT REQUIREMENTS

All ambient monitoring methods or analyzers used in SLAMS must be tested periodically to quantitatively assess the quality of the SLAMS data (Table 802.1). This includes both the automated (analyzers) and manual (samplers) methods.

802.1 PRECISION

The precision assessment is a check of the reproducibility of the measurements over a period of time. Somewhat different procedures and calculations are required for automated and manual methods.

802.1.1 Automated Methods

Appendix A of 40 CFR 58^{Reference 3} requires that a one point precision check be performed at least once every two weeks on automated analyzers for SO₂, NO₂, ozone, and CO. These precision checks are made by challenging the analyzer with certified gases of known concentration (traceable to either a NIST traceable reference material (NTRIM) or a NIST certified gas manufacturer's internal standard (GMIS)). The precision check gas must be 0.09 ± 0.01 ppm for the SO₂, NO₂, and ozone analyzers and 9.0 ± 1.0 ppm for CO analyzers. If the analyzers are operating at ranges other than the standard (0 to 1.0 ppm for SO₂, NO₂, and ozone or 0 to 100 ppm for CO) an appropriate precision check concentration must be approved by the U.S.EPA Regional Administrator.

Point analyzers must operate in their normal operating mode during the precision check. The test gas should enter as near as possible to the normal sampling inlet and pass through all tubing, filters, etc. that a normal sample would pass through. Some CO monitors with a large vent or purge flow that may be modified to reduce the flows or the test gas may directly enter the analyzer (bypassing the normal sampling inlet and filters) if such a modification is not likely to alter the monitor's response.

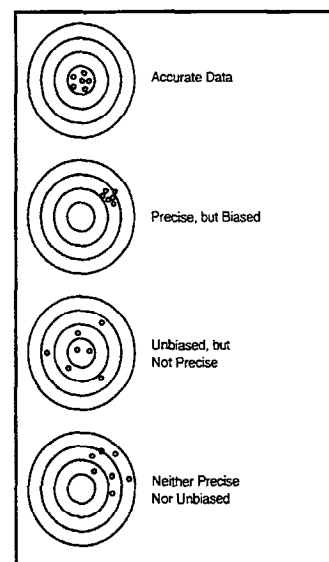


Figure 802.2
Accuracy of Data:
Bias and Precision

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Table 802.1 Minimum Data Assessment Requirements²

| Method | Assessment Method | Coverage | Minimum Frequency | Parameters Reported |
|---|--|--|--|--|
| Precision | | | | |
| Automated Methods for SO ₂ , NO ₂ , O ₃ , CO | Response check at 0.09 ± 0.01 ppm (9.0 ± 1.0 for CO) | Each analyzer | Once every two weeks | Actual concentration and measured concentration |
| Manual Methods: All methods except PM _{2.5} | Collocated samplers | 1 site for 1 - 5 sites 2 sites for 6 - 20 sites 3 sites for >20 sites (sites with highest concentration) | Once every six days | Particle mass concentration indicated by sampler and collocated sampler |
| Accuracy | | | | |
| Automated Methods for SO ₂ , NO ₂ , O ₃ , CO | Response check at 0.03 - 0.08 ppm 0.15 - 0.20 ppm 0.35 - 0.45 ppm 0.80 - 0.90 ppm (if applicable) | Each analyzer 25% of analyzers each quarter (at least one) | Once per year Each calendar quarter | Actual concentration and measured (indicated) concentrations at each level |
| Manual Methods for SO ₂ and NO ₂ | Check of analytical procedure with audit standard solutions | Analytical system | Each day samples are analyzed, at least twice per quarter | Actual concentrations and measured (indicated) concentrations for each audit solution |
| TSP and PM ₁₀ | Check of sampler flow rate | Each sampler 25% of samplers (at least 1) | Once per year Each calendar quarter | Actual flow rate and flow rate indicated by the sampler |
| Lead | Check of sample flow rate as for TSP | Each sampler | Include with TSP | Same as for TSP |
| | Check of analytical system with Pb audit strips | Analytical system | Each quarter | Actual concentration and measured (indicated) concentration of audit sampler (µg Pb per strip) |
| PM_{2.5} | | | | |
| Manual and automated methods - precision | Collocated samplers | 25% of SLAMS (monitors with concentrations affecting NAAQS violation status) | Once every six days | Particle mass concentration indicated by sampler and by collocated sampler |
| Manual and automated methods - accuracy and bias | Check of sampler flow rate | Every SLAMS monitor | Automated - once every two weeks; Manual - each calendar quarter (4/year) | Actual flow rate and flow rate indicated by the sampler |
| | Audit with reference method | | Minimum of four measurements per year | Particle mass concentration indicated by the sampler and by audit reference sampler |

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Open path analyzers present a somewhat different scenario. For these instruments a test cell containing a precision check gas is inserted into the path. As would be expected, the normal monitoring path should be modified as little as possible. This means using the normal reflectors, etc. to the maximum extent possible. The actual test gas concentration must be selected to produce the effective concentration discussed above (see Section 401.3 for a discussion of the concentrations required).

Precision checks of open path instruments have an additional complication -- the results must be corrected to remove the atmospheric concentration of the pollutant contained in the path. A corrected concentration is obtained by subtracting the atmospheric concentration immediately before and after the test. The atmospheric concentration must be less than 20% of the precision test gas concentration, otherwise the test should be discarded and repeated. If possible, the precision test for open path instruments should be conducted when the atmospheric concentrations are low and steady.

The data for the precision tests of automated instruments should be reported as the actual (certified) concentration (C_A) (or equivalent concentration for path instruments), measured concentrations (C_M), and percent difference (%D).

$$\%D = \frac{C_M - C_A}{C_A} \times 100$$

The precision of automated PM_{10} and $PM_{2.5}$ analyzers is checked by checking the operational flow rate of the analyzer. This is accomplished by using a certified flow rate transfer standard. When selecting and using a flow rate transfer standard care must be exercised to be certain that the transfer standard does not alter the operational flow rate of the analyzer.

Another way of measuring precision for both the automated and manual methods for $PM_{2.5}$ is by using collocated samplers. At least 25% (at least one) of the monitors must be collocated with the first collocated monitor being a Federal reference method monitor. Collocated reference method monitors must also be of the same method designation. Of the collocated equivalent method monitors, 50% must be collocated with monitors of the same method designation and 50% must be with reference method monitors.

In order to assure that the collocated samplers are representative of the same conditions, they must be within four meters of each other, but to avoid interfer-

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ence, they must be at least two meters apart (one meter apart for low flow [less than 200 liters/min] samplers).

802.1.2 Manual Methods

For manual methods other than $PM_{2.5}$ at least one site (Table 802.2) should be chosen for collocated sampling. Additional sites are encouraged for greater confidence in the statistics. PM_{10} and TSP sites having concentrations in the highest 25% in the reporting region should be selected for the collocated sampling. As with the collocated samplers discussed above for automated methods, the samplers must be between two and four meters apart.

**Table 802.2 Duplicate
(Collocated) Sampling for
Precision of Manual Methods
Other than for $PM_{2.5}$**

| Number of Reporting Sites | Number of Collocated (Duplicate) Sites |
|---------------------------|--|
| 1 - 5 | 1 |
| 6 - 20 | 2 |
| 21+ | 3 |

802.2 ACCURACY

Accuracy is the degree of agreement of the measured value and the reference value. Accuracy includes the bias (systematic error) and precision (discussed above).

Each calendar quarter at least 25% of the ambient air monitors for SO_2 , NO_2 , ozone, and CO must be audited. Over the course of a year all monitors must be audited. The audits should be conducted by personnel other than the station operator or analyst involved in the normal operation of the monitoring.

Table 802.3 Audit Gas Concentrations
(* audit level 4 is frequently omitted unless needed)

| Audit Level | Concentration Range (ppm) | | |
|-------------|---------------------------|-------------|----------|
| | SO_2 and Ozone | NO_2 | CO |
| 1 | 0.03 - 0.08 | 0.03 - 0.08 | 3 - 8 |
| 2 | 0.15 - 0.20 | 0.15 - 0.20 | 15 - 20 |
| 3 | 0.35 - 0.45 | 0.35 - 0.45 | 35 - 45 |
| 4 | 0.80 - 0.90* | ---- | 80 - 90* |

The audits are made by challenging the analyzers with certified gases at several points on the analysis range (Table 802.3). Unless otherwise precluded, these audits must be conducted

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through the entire sampling system including all filters, scrubbers, conditioners, and other inlet components used in normal ambient air sampling.

The NO₂ instruments are generally audited by gas phase titration in which NO from a certified cylinder is reacted with ozone to generate NO₂ in the appropriate levels. The NO₂ audit gas for chemiluminescent analyzers must also contain at least 0.08 ppm NO.

Audits of open path instruments are conducted by inserting a test cell containing audit gas concentrations that will give an equivalent concentration to Table 802.3. The instrument should be modified as little as possible. If possible, the audit should include the normally used transmitter, receiver, and reflector. Since, like in precision checks of open path instruments, the readings from the instrument are the sum of the ambient pollutant and audit gas concentrations, the audit must be corrected to remove the ambient concentrations to give the proper audit levels (Table 802.3). This procedure is the same as was discussed in the precision check section above.

The goal for the uncertainty for PM_{2.5} measurements has been defined as 10% coefficient of variation for precision and 10% for total bias. The precision is measured as discussed above. Bias of the PM_{2.5} measurements is determined by a check of the flow rate and an independent Federal Reference Method (FRM) audit. The FRM audits are to be conducted under the National Performance Audit Program (NPAP, see Section 804.3) or a comparable program. Twenty-five percent of the SLAMS monitors must be audited with a FRM audit each year. In addition to the blanket bias audit requirements, at least 25% (at least one per quarter and four per year) of each designated reference method or equivalent method monitors must be audited per year.

802.3 REPORTING

Periodically, reports to the EPA, ARB (or other state agency), local air district, etc. must be made. Specific data forms are used to provide a consistent format for recording information that will become part of a database. States and districts may devise their own format; however, data submitted to AIRS must be in the AIRS AQS format. With computer data acquisition programs the data can readily be formatted as needed and an output file to the report receiving agency generated. Computer data acquisition and the automated generation of the formatted reports can help in minimizing data entry errors.

802.3.1 Quarterly Reports

For each quarter, the results of all precision, bias, and accuracy tests conducted during that quarter should be reported. Results from invalid tests, tests carried out during a time period for which ambient data immediately prior or subsequent to the tests were invalidated, and tests of methods and analyzers other than the EPA approved methods and analyzers should be reported, but the results should be flagged so that it will not be utilized for quantitative assessment of precision, bias, and accuracy. For valid tests and methods, all data gathered during the reporting period must be submitted within 90 days of the end of the quarter.

802.3.2 Annual Reports

When all precision, bias, and accuracy estimates have been conducted for all four quarters of the calendar year, the EPA will calculate and report the measurement of uncertainty for the entire year. These results will then be associated with the data submitted in the annual SLAMS Report. The data required in the reports should be construed as the minimum necessary statistics needed by the EPA to overview national air quality status and convey information to interested parties.

Most air pollution control agencies publish air quality summaries for their area of purview. The EPA encourages their continuance and expansion, where appropriate, to include air quality trends, population trends and exposures, and pollutant distribution. The agencies may want to also include the SLAMS report information into their local reports.

The annual SLAMS Report is a summary of all ambient air monitoring data from all monitoring stations designated as SLAMS stations in the reporting region. The report covers a calendar year (1 January to 31 December) and must be submitted (and certified by the senior air pollution control officer) by 1 July of the following year.

The information required in the SLAMS report varies by pollutant. Tables 802.1 - 802.3 summarize the information needed. Time of occurrence means the time of the end of the sample in question; i.e. the time of occurrence of a CO sample lasting from 12:01 a.m. to 8:00 a.m. would be 8:00 a.m.

The air quality concentration should be rounded to the number of significant digits used in specifying the concentration. The digit to the right of the last

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**Table 802.1
Site and
Monitor
Information for
SLAMS Reports**

*list dates and
measurements for
episodes and
unscheduled sampling
and date preceeding the
episode or
unscheduled sample

| Parameter | City | County | Street Address | AIRS-- AQS Site Code | AIRS-- AQS Method Code | Number of Hourly Obs | Number of Daily Obs | Sample Sched. | Number of Add. Sample Days | Episode and Un- sched. Data* |
|-------------------|------|--------|-------------------|-------------------------------|---------------------------------|-------------------------------|------------------------------|------------------|-------------------------------------|---------------------------------------|
| SO ₂ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | |
| CO | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | |
| NO ₂ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | |
| Ozone | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | |
| TSP | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ |
| PM ₁₀ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ |
| PM _{2.5} | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ |

Table 802.2 Annual Summary Statistics for SLAMS Reports

†Average and date of occurrence

*Average, date, and time of occurrence

| Parameter | Annual Arith. Mean | Quarterly Average | Highest 24-Hour Average* | Second Highest 24-Hour Average* | Highest 8-Hour Average* | Second Highest 8-Hour Average* | Highest 3-Hour Average* | Second Highest 3-Hour Average* | Highest 1-Hour Average* | Second Highest 1-Hour Average* | Daily Max.* | Number of 24- Hour Exceed- ances | Number of 8-Hour Exceed- ances | Number of 3-Hour Exceed- ances | Number of 1-Hour Exceed- ances | Number In Concen- tration Ranges |
|-------------------|--------------------------|----------------------|--------------------------------|--|-------------------------------|---|-------------------------------|---|-------------------------------|---|----------------|--|---|---|---|--|
| SO ₂ | ✓(ppm) | | ✓(ppm) | ✓(ppm) | | | ✓(ppm) | ✓(ppm) | | | | ✓ | | ✓ | | ✓(24-hr) |
| CO | | | | | ✓(ppm) | ✓(ppm) | | | ✓(ppm) | ✓(ppm) | | | ✓ | | ✓ | ✓(8-hr) |
| NO ₂ | ✓(ppm) | | ✓(ppm) | ✓(ppm) | | | | | ✓(ppm) | ✓(ppm) | | | | | | ✓(1-hr) |
| Ozone | | | | | | | | | | | 4 highest | | | | ✓ | ✓(daily max) |
| TSP | ✓(µg/m3) | | | | | | | | | | | list up to 10 | | | | ✓(24-hr) |
| PM ₁₀ | ✓(µg/m3) | | | | | | | | | | | ✓ | | | | ✓(24-hr) |
| PM _{2.5} | ✓(µg/m3) | | | | | | | | | | | ✓ | | | | ✓(24-hr) |
| Lead | | ✓(µg/m3) | | | | | | | | | | | | | | ✓(number of samples in quarter) |

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Table 802.3 Number of Samples per Range of Concentrations for SLAMS Reports

| SO ₂ , NO ₂ , Ozone (ppm) | Range of Concentrations | | | | Number of Values |
|--|-------------------------|--------------------------|--|--|---------------------|
| | CO (ppm) | TSP (µg/m ³) | PM ₁₀ (µg/m ³) | PM _{fine} (µg/m ³) | |
| | | | 0 - 25 | | |
| 0.00 - 0.04 | 0 - 4 | 0 - 50 | 26 - 50 | | |
| 0.05 - 0.08 | 5 - 8 | 51 - 100 | 51 - 75 | 0 - 15 | |
| 0.09 - 0.12 | 9 - 12 | 101 - 150 | 76 - 100 | 16 - 30 | |
| 0.13 - 0.16 | 13 - 16 | 151 - 200 | 101 - 125 | 31 - 50 | |
| 0.17 - 0.20 | 17 - 20 | 201 - 250 | 126 - 150 | 51 - 70 | |
| 0.21 - 0.24 | 21 - 24 | 251 - 300 | 151 - 175 | 71 - 90 | |
| 0.25 - 0.28 | 25 - 28 | 301 - 400 | 176 - 200 | 91 - 110 | |
| Greater than 0.28 | Greater than 28 | Greater than 400 | Greater than 200 | Greater than 110 | |

significant digit determines the rounding process. If this digit is greater than or equal to 5, the last significant digit is rounded up. The insignificant digits are truncated. For example: 100.5 µg/m³ rounds to 101 µg/m³ and 0.1245 ppm rounds to 0.12 ppm.

In addition to the data summary, the SLAMS Report must include a summary of the occur-

rences in which the ambient concentrations reached or exceeded the NAAQS. For each occurrence, the location, date, pollution source, and duration of the occurrence must be reported.

803 CALIBRATIONS AND AUDITS

Before valid data can be returned by a monitoring instrument, it must be calibrated. Calibration of an analyzer establishes the quantitative relationship between the instrument response (chart recorder reading, output voltage, digital output, etc.) and the pollutant concentration (ppm, ppb, µg/m³, etc.). Once established by calibration to a certified concentration, this relationship is used to convert analyzer responses to the corresponding ambient pollutant concentration readouts. Since analyzers tend to change their response over time (drift), the analyzers must be periodically audited to check for any drift in the analyzer's response; if a significant amount of drift has occurred the analyzer calibration must be updated (i.e. recalibrated) to maintain the high degree of accuracy required by ambient monitoring programs. To minimize drift, most analyzers are required to be operated in heated/air conditioned monitoring stations.

Each analyzer should be calibrated as directed by the manufacturer's operation and instruction manuals and in accordance with general guidance provided in the CFR subparts, the EPA's reference and equivalent method promulgations, EPA's Quality Assurance Handbook², and other references. Detailed calibration proce-

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dures for reference methods for CO, NO₂, and ozone are contained in the appropriate appendix to 40 CFR 50.⁴

New analyzers should be checked-out in the office or receiving laboratory prior to sending to the monitoring station. Calibration of the instrument; however, should be carried out at the monitoring station in the conditions under which it will operate. Before calibration the analyzer should warm-up and equilibrate to the ambient conditions for at least several hours (preferably overnight) before beginning calibration. During calibration the analyzer should be operated in its normal operating mode, emulating (as nearly as possible) sampling of ambient atmospheres. The calibration gases should pass through all filters, scrubbers, conditioners, converters, etc. that an ambient sample would pass through. All operational adjustments should be completed before calibrating the instrument. In addition, analyzers that will be used on more than one range (or that have autoranging capability) should be calibrated separately on each range.

803.1 CALIBRATION STANDARDS

When calibrating an analyzer, it is generally allowed to sample and analyze a test gas mixture of the pollutant in question at a known concentration in air. The test atmosphere should as closely as possible emulate the ambient atmospheric gas matrix that the analyzer will be exposed to while making routine measurements. For that reason the calibration standards should be in clean air rather than an artificial mixture (unless another matrix is required for storage stability). All non-zero test concentrations must be, or be derived from, standards that are certified as traceable to a NIST primary standard. Normally, the working standard should be certified directly to the SRM or CRM, with an intervening intermediate standard only when necessary. Direct use of a CRM as the working standard is acceptable, but direct use of an NIST SRM is discouraged because of the limited supply and the expense of SRM's. The certification of the working standard should:

- establish the concentration of the working standard relative to the primary standard
- certify that the primary standard (and hence the working standard) is traceable to an NIST primary standard
- include a test of the stability of the working standard over several days

- specify a recertification interval for the working standard

Test concentrations of ozone cannot be stored and therefore must be generated for the calibration. The transfer standard must be traceable to a primary standard UV photometer as described in 40 CFR 50 Appendix D.⁴

Test concentrations at zero concentrations are considered valid standards. Although they are not required to be traceable to a primary standard, care should be exercised to ensure they are adequately free of all substances likely to be detectable by the analyzer.

Flow and volume transfer standards should be calibrated and certified at appropriate intervals (usually every three to six months) against NIST or other authoritative standards such as a traceable bubble meter or gas meter.

803.2 CALIBRATIONS

Analyzers in routine operation should be recalibrated periodically to maintain close agreement between the calibration relationship used to calculate pollutant concentrations from the analyzer output and the actual pollutant concentrations. The frequency of calibration is a trade-off between the stability of the analyzer under prevailing temperatures, pressures, line voltage variations; the cost and convenience of carrying out the calibrations, etc.; the quality of ambient measurements needed; the number of measurements lost during the calibrations; and the risk of collecting invalid data due to malfunctions and other analyzer problems that wouldn't be discovered until a calibration is carried out. A new instrument may need frequent level 1 or multipoint calibrations until reliability of the instrument can be established. After enough information on the drift performance has been accumulated the frequency of calibrations can be adjusted given the conditions under which the analyzer will be operating.

803.2.1 Multipoint Calibrations

A multipoint calibration is used to establish or verify the quantitative relationship between the instrument response (chart recorder reading, output voltage, digital output, etc.) and the pollutant concentration (ppm, ppb, $\mu\text{g}/\text{m}^3$, etc.) and to verify the linearity of the analyzer. A multipoint calibration should be conducted at least twice per year, although a multipoint audit may serve in lieu of one of these.

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Multipoint calibrations consist of three or more test concentrations, including a zero concentration, a high level concentration at 80% to 90% of the full scale range of the analyzer, and one or more intermediate concentrations spaced approximately equally over the scale range. The more test points used the better the statistical calculations of the calibration parameters; three points generally is sufficient for a linear instrument. Most modern analyzers have a linear (or very nearly linear) response with concentration; however, if a nonlinear analyzer is being calibrated, additional test points should be employed.

Table 803.1 Linear Regression Criteria

| Parameter and Evaluation | Value | Conditions |
|--------------------------|-------------------------|---|
| Slope | | |
| Excellent | $\leq \pm 5\%$ | Between analyzer response and audit concentration |
| Satisfactory | $\pm 6\%$ to $\pm 15\%$ | |
| Unsatisfactory | $> \pm 15\%$ | |
| Intercept | | |
| Satisfactory | $\leq \pm 3\%$ | Of analyzer range |
| Unsatisfactory | $> \pm 3\%$ | |
| Correlation Coefficient | | |
| Satisfactory | 0.9950 to 1.0000 | Linear analyzer response to audit concentration |
| Unsatisfactory | < 0.9950 | Non-linear response to audit concentrations |

Before beginning the calibration the zero and span adjustments should be made if necessary (on a recalibration of an existing analyzer the "as is" unadjusted zero and span values should be measured before any adjustments are made). Since the zero and span controls often interact with each other, the adjustments may have to be repeated several times to obtain the desired final adjustments.

After the final adjustments have been made the three (or more) calibration standards should be introduced to obtain the final calibration. The analyzer response readings should be made from the display that will be used to obtain the routine pollutant concentration readings. The analyzer readings should then be plotted against the concentrations and the best linear (or nonlinear if appropriate) curve to fit the points determined. The responses should be plotted in the field while taking the data so, if any point does not fit a linear curve, it can be investigated and repeated, if necessary. Least squares regression analysis (with the appropriate transformation for nonlinear analyzers if necessary) should be used to determine the slope and intercept for the best fit calibration line. The calibration line takes the form of $y=mx+a$, where y is the analyzer response, m is

the slope of the regression line, x is the pollutant concentration, and a is the x -axis intercept. When this regression line is used to calculate the pollutant concentration from the analyzer output the formula takes the form of: $x=(y-a)/m$. Criteria to judge the analyzer performance are normally specified by the operating agency. Table 803.1 lists the regression criteria used by the ARB.

803.2.2 Level 1 Zero and Span Calibrations

The level 1 zero and span calibration is a simplified, two-point analyzer calibration that may be used when the analyzer linearity does not need to be checked or verified. Since most analyzers have a reliably linear (or near-linear) output response with pollutant concentrations, they can frequently be adequately calibrated with only two concentration standards. Frequent checks or updates of the calibration relationship with a two-point zero and span calibration improves the quality of the monitoring data by helping to keep the calibration relationship more closely matched to any drift in the analyzer response.

One of the standards may be a zero concentration, which can be relatively easily obtained and does not need to be certified. The second standard should be 70% to 90% of the analyzer's full scale measurement range and must be certified.

As with any calibration or audit, the analyzer should be operating in its normal sampling mode and the test gases should flow through as much of the inlet and sample conditioning system as practicable. Stations configured as per the ARB configuration have a calibration line that tees into the sampling system at the sample inlet. Wet and dirty sample lines and particulate filters can cause changes in the pollutant concentrations. This is important for NO_2 and SO_2 and particularly for ozone. Comparison of the analysis of a calibration gas introduced at the inlet with the same gas introduced at the back of the instrument can serve as a check of the cleanliness of the sample line or as a check for leaks in the line.

As a general procedure, a level 1 zero and span calibration may be conducted as follows:

Connect the calibration system, leaving the analyzer in its normal operating mode and making no other changes or adjustments to the analyzer.

- Sample and measure the span test standard gas. Record the unadjusted, stable ("as is") span response.

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- Sample and measure the zero test standard gas. Record the unadjusted, stable ("as is") zero response.
- Perform any needed maintenance and adjustments to the analyzer.
- Resample and measure the zero test standard gas. Adjust the zero reading if necessary until a stable reading is obtained at the desired level accounting for any zero offset used. Record the new zero reading.
- Resample and measure the span test standard gas. Adjust the span reading if necessary. Record the new span reading.
- If any adjustments are made allow the analyzer to stabilize at the new settings and recheck the zero and span values, readjust if necessary, and record the new readings. This step is repeated iteratively until stable reading at the desired levels are attained.

After the calibration has been completed the new calibration relationship ($y=mx+a$) should be plotted using the zero and span readings or the intercept and slope determined as follows:

$$a = \text{intercept} = \text{zero}$$
$$m = \text{slope} = \frac{\text{span} - \text{zero}}{\text{span concentration}}$$

803.3 LEVEL TWO ZERO AND SPAN CHECKS

Level two zero and span checks are designed to be quick and convenient checks of the analyzer performance between zero and span or multipoint calibrations. As such the level two checks are generally conducted more frequently than level one or multipoint calibrations; the EPA only requires two level two checks per month. The ARB policy is to conduct five level two checks at a low level (between 10 and 20% of scale) and two at a high level (approximately 80% of scale each week; i.e. one level two check each night.

The level two checks are simplified by not requiring certified test gas concentrations or simulation devices, although the standards used are usually traceable to NIST at the tertiary level. For that reason they are not an "official" check of the analyzer's response and cannot be used as a basis for analyzer zero or span adjustments, calibration updates, or adjustments of ambient data. Their primary

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purpose is to detect monitor malfunctions and calibration drift. Whenever a level two check indicates a possible calibration problem, a level one zero and span or multipoint calibration should be carried out before any corrective action is taken.

The level two zero and span check is conducted like a level one calibration in that the analyzer is checked with a zero and upscale concentration of the pollutant in question. The major difference is that the level two is just a check of the analyzer function without any adjustments and that it uses less expensive uncertified gases and services. The level two check may also check only the analyzer response rather than the entire sampling and analysis system (although the gases may be introduced at the inlet as are other calibrations and checks). If the level two check is conducted at the instrument back it should be kept in mind that other parts of the system may also contribute to changes in the instrument's response.

If a level two zero and span check is to be used in the quality control program, a reference response should be obtained by conducting a level two check immediately after the zero and span or multipoint calibration, while the analyzer's calibration is accurately known. Subsequent level two checks should be compared to the most recent reference response, not to the preceding level two check.

803.4 ANALYZER ADJUSTMENTS

As previously indicated, analyzers should not be adjusted without first confirming the "as is" condition. Most typically, this is by a level one zero and span calibration. If an analyzer has been operating well, it is often preferable to not make any adjustments when relatively small adjustments would be indicated. Ideally, all ambient measurements should be calculated from the most recent calibration (either level one zero and span calibration or multipoint calibration) or on the basis of both the previous and subsequent calibrations. In the latter case the slope and intercept employed for an individual ambient reading are based on the linear interpolation of the slope and intercept of the previous calibration and the unadjusted values from the subsequent calibration. In this case considerable drift from the original response curve can be tolerated before adjustments to the analyzer are needed since the calibration curve used to calculate the ambient measurements is kept in close agreement with the actual analyzer response.

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If frequent updates of the calibration curve are not available, the ambient reading must be calculated from the most recent calibration curve. In this case the zero and span calibrations and checks serve only to monitor for monitor malfunction and drift error. Since the calibration curve is not updated as frequently, it is critical to remove the drift error by adjustment.

To facilitate the process of determining the calibration frequency and to keep track of instrument drift it is recommended that the station operator construct control charts. Control charts visually represent and statistically monitor the zero and span drift. Figure 803.1 illustrates a control chart. When the cumulative drift shown by plotting the zero and span deviation reaches one of the control limits the operator should make the appropriate adjustments. As can be seen in the figure, the drift may vary from day to day without adjustment and

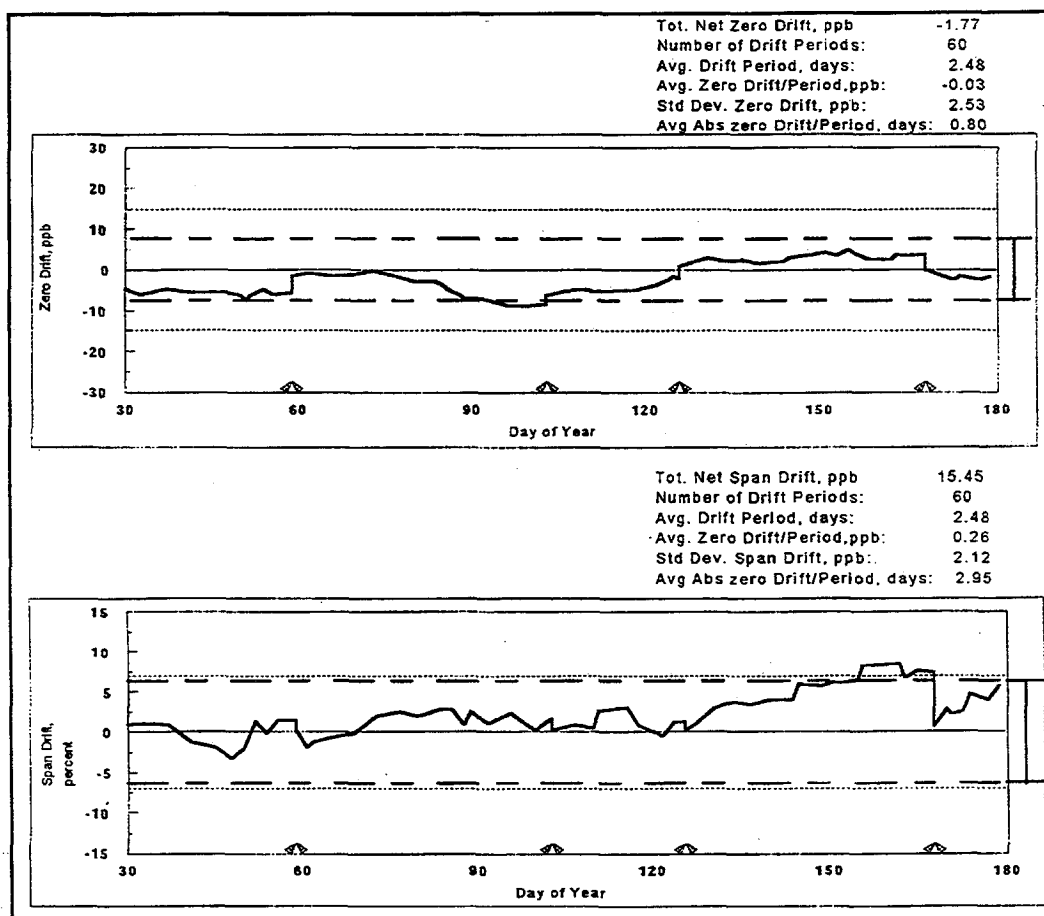


Figure 803.1 Example Control Chart²

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"chasing" the zero or span value may make the operation of the instrument worse than waiting until the cumulative drift reaches the control limit. In this figure, the adjustment limits were set at $\pm 15\%$ for the zero and $\pm 7\%$ for span, although most of the span adjustments and all of the zero adjustments were made before these limits were exceeded. In this case the calibration slope and intercept were updated at each zero and span calibration. Narrower limits may be needed if the calibration curve used to calculate the ambient data is not updated at each calibration.

The total net cumulative zero drift over the 180 day period (ignoring zero adjustments) was -1.77 ppb, indicating that the analyzer's zero stability was good. The total net cumulative span drift was $+15.45\%$, indicating that the analyzer should be watched closely for continued positive span drift.

An additional way of looking at the drift is shown in Figure 803.2. In this figure a band equal to three standard deviations can be established to represent the normal performance of the analyzer. An excursion outside these bands is an indication of a possible performance problem that may need corrective action or additional scrutiny.

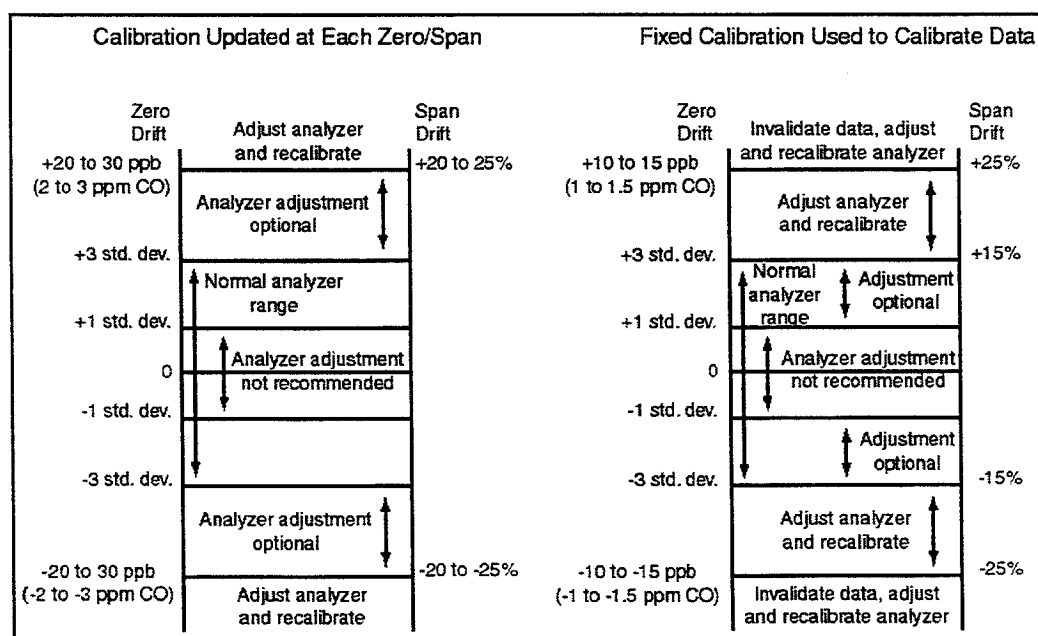


Figure 803.2 Suggested Zero and Span Drift Limits²

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Some analyzers are capable of automatically making the zero and span adjustments. If the automatic zero and span calibration meets all the requirements of the level one zero and span calibration and both the adjusted and unadjusted response values may be obtained from the data recording device, then the calibration may be treated as a valid zero and span calibration.

When zero or span drift validation limits are exceeded, ambient measurements should be invalidated back to the most recent point in time when such measurements are known to be valid. Generally this point is the previous calibration, audit, or other valid QC check; unless some other point in time can be identified as the probable cause (such as a power failure or analyzer malfunction) of the excessive drift. Data following an analyzer malfunction or period of non-operation should be regarded as invalid until the next calibration unless unadjusted zero and span readings at the calibration can support its validity.

804 EXTERNAL AUDITS

The performance audit is used to validate and document the accuracy of the data generated by a measurement system. As an external procedure (i.e. conducted by someone not directly associated with the monitoring effort) it provides assurance of an unbiased assessment of the program. Additional information about precision and accuracy audits can be found in Sections 802.1 and 802.2 of this manual and in the EPA Quality Assurance Handbook.²

The performance audit procedures provide an assessment by challenging the monitoring instruments with certified reference materials and transfer standard equipment. Some of these methods include: multiple compressed gas cylinders, dynamic dilution of higher level concentrations from certified cylinders using certified dilution equipment, gas phase titrations, UV photometry, and flow rate measurements.

If any data at the monitoring station is reduced by hand the station operator should carry out those calculations as normal. This procedure allows evaluation of the total monitoring system including the station operator, equipment, and procedures.

Upon completion of an audit, all monitoring equipment should be reconnected and returned to the configuration in which it was found. To facilitate this, the auditors should record any settings, etc. as they were found upon arrival at the

station. In addition, all audit calculations should be completed before leaving the station to ensure that no extraneous or inconsistent differences exist in the data. Sometimes a recording mistake is found after completing the audit, if the error is found before leaving the station it may be able to be rectified while still on site.

804.1 AUDIT MATERIALS

Audit procedures and materials vary depending upon the parameter and equipment being audited, audit equipment, and preferred methods of the auditing organization.

Some of the auditing procedures and materials include permeation tubes, dynamic dilution of compressed gases, gas phase titration, multiple compressed gas cylinders, UV photometry, and flow rate measurements (Table 804.1). The

Table 804.1 Audit Materials and Procedures²

| Pollutant | Audit Procedure |
|--|--|
| Sulfur dioxide | Dynamic dilution - permeation tube Dynamic dilution - compressed gas cylinder |
| Nitrogen dioxide | Gas phase titration |
| Carbon monoxide | Dynamic dilution - compressed gas cylinder Multiple compressed gas cylinders |
| Ozone | Ultraviolet photometry |
| Particulate matter (TSP, PM ₁₀ , PM _{2.5}) | Flow rate measurement |

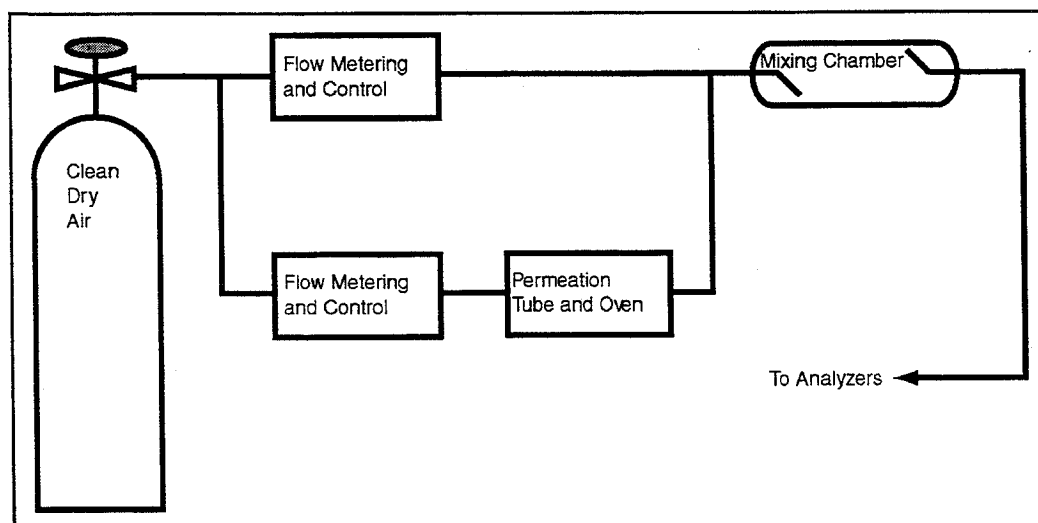


Figure 804.1 Permeation Tube Audit System

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general guidelines for performance audits are the same for all procedures and material.

804.1.1 Dynamic Dilution - Permeation Tubes

Permeation tubes are devices that contain very high concentrations (often pure, 100%) of the pollutant in question and are permeable in that they allow a constant "leakage" of the pollutant to escape. The permeation rate of the device is known, allowing a steady airstream of known concentration to be generated. This airstream can then be diluted with varying amounts of clean, dry air to produce the audit test concentrations needed (Figure 804.1).

The most common pollutant analyzers audited are those for sulfur dioxide. Dynamic dilution using permeation tubes has an accuracy of $\pm 2.5\%$ if all portions of the system are calibrated, certified, and properly operated.

One of the most important factors of accuracy of a permeation tube audit system is that the temperature of the permeation tube chamber must be very well controlled. The permeability of the source generally varies strongly with the temperature of the system, causing a wide variation of the source if the temperature is not well controlled. The temperature must be controlled to an accuracy of $\pm 0.10^\circ\text{C}$. The system should have a readout sensitive enough to verify the temperature of the permeation device during operation.

Since this is a dynamic dilution system, it is important to thoroughly mix the source air stream containing the high concentration of pollutant with clean dry air. Glass mixing chambers in the range of 100 to 500 cm³ are generally used.

The diluent source must provide clean dry air to the system. A grade 0.1 compressed gas cylinder may be used. A clean air supply system may also be used; however, the system must not remove CO₂ from the ambient airstream. When using a flame photometric analyzer, a diluent source which contains approximately 350 ppm CO₂ is required.

The sample lines of the audit system should supply the analyzers with test atmospheres at ambient pressure. The tubing should be of sufficient diameter to ensure minimum pressure drop, but of small enough diameter to minimize the residence time in the sample line. The sample lines must be nonreactive to the pollutants being analyzed. For most parameters this means glass or teflon

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tubing. However, teflon is not recommended for hydrocarbon sampling due to its reactivity with many hydrocarbon species.

Before beginning an audit using a permeation device, it must be allowed to equilibrate. As was discussed above, the temperature must be maintained within $\pm 0.1^{\circ}\text{C}$. This takes from several hours to an entire day. Temperature changes of 1 or 2 degrees require approximately 3 hours to fully equilibrate; for temperature changes of 10 degrees or more an equilibration period of 24 hours is advisable.

After the audit system has been setup and equilibrated, the start time of the audit should be recorded. The station should be taken off-line if it is on-line to a remote data server so audit data is not mistakenly interpreted as ambient data. This should be arranged before the audit date to prevent conflicts with the needs of the users of the data. If a strip chart is used, a note should be recorded on the chart at the beginning and end of the audit.

The audit gas should be introduced into the system with an excess of 10% to 50% above the flow rate required by the instruments. The audit gas should be introduced at the sample inlet point if possible. In this manner the entire monitoring system is audited. If an instrument fails an audit it sometimes is useful to introduce the audit gas directly into the instrument to help localize the source of the error as an error in the instrument or in the sampling system. The excess audit gas should be vented from the system (being careful not to cause an excess pressure at the instrument) in a manner that prevents the vented gas re-entering the system and also prevents exposure of the audit and station personnel.

Audit concentrations consistent with the requirements of 40 CFR 58, Appendix A should be generated and introduced sequentially into the system (see Section 802). The usual sequence of concentrations is to start with a pre-zero then the highest concentration, the the mid-level concentration, etc. and ending with a post-zero, although the order is not specified in the CFR. When changing the audit concentrations the air flow through the permeation tube chamber should remain constant. To achieve different concentrations the diluent air flow should be adjusted; increasing the air flow for lower concentrations and decreasing the air flow for higher concentrations.

The responses from audit instruments and monitoring station instruments recorded. A standardized form that suits the procedures used by the auditing

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agency should be developed by that agency, the form used by the ARB is included in the Appendix of this manual and is discussed in Section 804.2.

After auditing the monitoring system at all concentrations the percent difference for all points and a regression analysis should be calculated.

804.1.2 Dynamic Dilution - Compressed Gas Cylinders

Conducting audits using the dynamic dilution of cylinder gases is very similar to conducting the audits by dynamic dilution using permeation tubes (Section 804.1.1) except that the concentrated pollutant source is a certified cylinder containing the pollutant gas rather than the permeation tube generator. The source cylinder can contain multiple gases, allowing several analyzers in the monitoring station to be audited simultaneously.

804.1.3 Gas Phase Titration

Gas phase titrations are the principle method used to audit nitrogen dioxide monitoring equipment. Nitrogen dioxide, especially in combination with other pollutants, is not stable in gas cylinders. Therefore, the needed NO_2 is generated by converting NO into NO_2 . The NO and NO_x channels of a chemiluminescent NO_x analyzer are audited with certified concentrations produced by a dynamic dilution system which uses clean dry air to dilute a gas cylinder containing NO in nitrogen. After the completion of the NO - NO_x audits, NO is titrated with ozone to produce NO_2 . These audit data are used to evaluate the calibration of the NO - NO_x - NO_2 analyzer channels and to calculate the converter efficiency.

A gas phase titration system adds an ozone generator and a reaction chamber (similar to the regular mixing chamber) for the NO /ozone reaction to form NO_2 . The percent of the NO that is converted to NO_2 is controlled by the quantity of ozone added to the NO flow. There should always be approximately 0.08 to 0.12 ppm NO remaining after complete reaction of NO with ozone. Therefore, the NO_2 audit should use 0.08 to 0.12 ppm higher NO than the NO_2 audit concentration needed.

The NO_2 audit concentration is calculated as the difference between the original NO concentration and the remaining NO :

$$[\text{NO}_2]_A = [\text{NO}]_{\text{orig}} - [\text{NO}]_{\text{rem}}$$

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The station NO_2 response and concentration is read from the station instruments. The efficiency of the converter in the station NO_x instrument is calculated for each audit point as:

$$\% \text{ converter efficiency} = \frac{[\text{NO}_2]_A - [\text{NO}_x]_{\text{orig}} - [\text{NO}_x]_{\text{rem}}}{[\text{NO}_2]_A}$$

In addition, the percent difference for all points is calculated as is the regression for NO , NO_2 , and NO_x .

804.1.4 Multiple Compressed Gas Cylinders

Multiple compressed gas cylinder audits entail using separate certified compressed gas cylinders for each audit concentration. During the audit each cylinder is turned on in sequence and that concentration of pollutant gas is injected

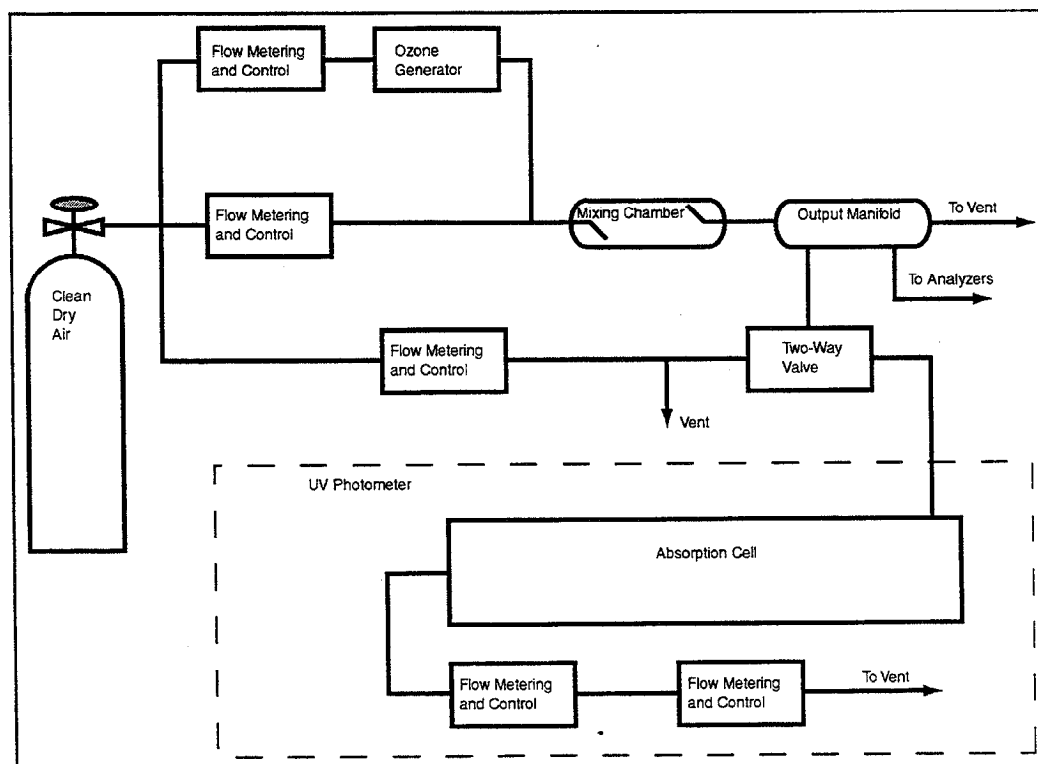


Figure 804.2 Schematic Design on an Ultraviolet Photometric Audit System

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into the system. As with other audits, the percent difference for each point and a regression analysis are calculated and reported.

804.1.5 Ozone Audits Using Ultraviolet Photometry

Since ozone cannot be stored in a cylinder, it must be generated on-site at the time of use. Ozone concentrations are generated using a UV ozone generator transfer standard. Each atmosphere generated is verified using UV photometry. Additional information on the principles of ozone measurement by UV photometry are contained in Section 403.4 of this manual.

A UV photometer (Figure 804.2) generates a constant ozone concentration that is then diluted with clean, dry air to the desired working concentration. After formulating the working atmosphere the flow is split between the internal photometer and the station instrument to be audited. The mixing chamber, output manifold, and sample/connecting lines must be unreactive to ozone; glass or teflon are recommended. The clean, dry air used may be generated by an air purifying system or compressed gas cylinder. The clean, dry air must be free of contaminants such as NO, NO₂, extraneous ozone, or reactive hydrocarbons that would cause detectable responses in the system. The system must also be operated at atmospheric pressure, care must be exercised to prevent pressure in either the station analyzer or the transfer standard.

To conduct an ozone audit the output of the transfer standard UV photometer are introduced into the station sampling system. Generally, the audit atmosphere should be introduced into the station sampling inlet to test the entire monitoring system for errors introduced by the sampling line etc. in addition to any bias or imprecision of the analyzer. The start and stop times of the audit should be recorded on the analyzer output to prevent confusing the audit levels for ambient ozone levels.

After all test concentrations have been introduced and the audit concentration and station concentrations recorded, the station should be returned to normal operation. If significant differences between the audit concentrations and the station responses are evident an audit point or two directly introduced into the back of the monitoring instrument can sometimes determine if the problem lies in the analyzer or the sampling system.

The percent difference between the audit concentrations and station responses and the least squares slope, intercept, and correlation coefficient should be calculated to determine analyzer performance.

804.1.6 Flow Audits of Particulate Instruments

Other than using somewhat esoteric laboratory-type equipment, it is very difficult to audit a particulate sampler/monitor in the manner that gas monitors are audited (i.e. injecting known pollutant concentrations). What is left, therefore, is to audit the sampler flow rate and assume that the measured concentration is adequately represents the ambient concentration.

Calibrated flow rate transfer standards are the primary means of auditing the flow of particulate samplers and monitors. The most common device used to audit hi-vol based TSP and PM_{10} samplers is the reference flow (ReF) device. The ReF is an orifice meter that uses a series of orifice plates (or a continuously variable diaphragm) to restrict the flow rate. The pressure drop across the flow restriction is related to the flow rate through the certification calibration equation.

An alternative to the ReF, frequently used for TEOM and $PM_{2.5}$ audits, is the mass flow meter (MFM). A mass flow meter measures the mass of air flowing through the system. The volume of airflow is calculated through the MFM's calibration equation and the temperature and pressure during the audit. MFMs are often used in cases where the pressure drop of an orifice meter (ReF type devices) will alter the flow characteristics of the sampler since MFMs are generally low pressure drop devices.

When auditing a hi-vol sampler it is important to know whether the sampler was calibrated in terms of the actual condition at the time of calibration, seasonal average conditions, or if the flow rates have been corrected to standard temperature and pressure. The comparison between audit and station flow rates must be made with the same units and corrections. It is also important to know whether the sampler being audited is equipped with a flow controller.

Auditing samplers equipped with flow controllers - Most hi-vol samplers equipped with flow controllers are calibrated in terms of the standard flow rate.

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Conduct the audit as follows:

- Remove the filter hold down clamps from the sampler and have the operator remove any filter (either exposed on the previous sampling period or loaded and ready for the next) on the sampler.
- Place a clean filter of the type used for sampling (generally glass fiber filters) and fasten the ReF to the sampler. When auditing samplers equipped with flow controllers, no restriction plate is used in the ReF device.
- Install the wind deflector if necessary and connect and zero the water manometer.
- Start the sampler and allow to warm up for approximately 25 minutes until stable. Record the pressure drop indicated on the manometer(inches of water column), ambient temperature (EC), barometric pressure (mm Hg), and station flow rate (obtained from the station operator). The barometric pressure can be obtained by a barometer (preferred) or by calculation from the station elevation ($P_b = 760 - (\text{elevation in meters} \times 0.076)$).
- Calculate the percent difference between the reference and station flow rates.
- At the conclusion of the audit have the station operator replace the filter and reset the timer as it was before the audit.

Auditing samplers without flow controllers - Hi-vol samplers without flow controllers are typically calibrated in terms of the actual flow rate.

An audit of a sampler with out a flow controller is conducted like the samplers with flow controllers with a few alterations:

Do not place a filter on the sampler during the audit.

Conduct the audit using the restriction plates beginning with the 18 hole plate and continuing with all plates. An audit of a sampler with a flow controller results in a single data point while an audit of a sampler without a flow controller results in five data points.

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Since an audit of a sampler without a flow controller results in multiple data points, calculate the least squares regression coefficient, slope, and intercept in addition to the percent difference at each point.

Calculations - Calculate the audit flow rate at standard conditions for hi-vol samplers with flow rates corrected to standard temperature and pressure.

$$Q_{\text{std}} = \frac{1}{m} \left[\sqrt{\Delta H \left(\frac{P_b}{760} \right) \left(\frac{298}{T_a} \right)} - b \right]$$

where:

Q_{std} = standard flow rate (m^3/min)

m = slope from calibration coefficients determined during the calibration of the ReF device, using flow rates corrected to standard conditions.

b = intercept from calibration coefficients determined during the calibration of the ReF device, using flow rates corrected to standard conditions.

ΔH = pressure drop shown on the manometer (in. H_2O)

P_b = barometric pressure (mm Hg)

T_a = ambient temperature (in Kelvins [$273.16 + ^\circ\text{C}$])

Calculate the percent difference for each audit point as follows after converting flow rate data to standard conditions.

$$\% \text{ difference} = \frac{F_s - F_A}{F_A} \times 100$$

where:

F_s = station measured flow rate (std. m^3/min)

F_A = audit flow rate (std m^3/min)

For samplers calibrated in terms of the actual or seasonal average conditions, calculate the audit flow rate in terms of the actual conditions.

$$Q_{\text{act}} = Q_{\text{std}} \left(\frac{760}{P_b} \right) \left(\frac{T_a}{298.16} \right)$$

where:

Q_{act} = the actual flow rate (m^3/min)

Q_{std} = the standard flow rate (m^3/min)

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P_b = barometric pressure or seasonal barometric pressure (mm Hg)
 T_a = ambient or seasonal ambient temperature (in kelvins [$273.16 + ^\circ\text{C}$])

To convert for m^3/min to ft^3/min multiply by 35.31.

804.2 CALIFORNIA AIR RESOURCES BOARD AUDITS

The California Air Resources Board conducts performance audits of the ambient air monitoring instruments and systems audits of entire monitoring programs. The ARB also participates in the U.S.EPA's National Performance Audit Program (NPAP).

804.2.1 Through-The-Probe Audits

The California Air Resources Board Quality Assurance Section (QAS) conducts through-the-probe audits at monitoring stations throughout California. These audits are conducted by challenging the monitoring systems by introducing audit gases into the station inlet. Through-the-probe audits challenge not only the analyzing instruments, but also the entire air sampling system from the probe inlet through the analyzer. The audit gases are generated by dynamic dilution of high concentrations of certified NIST traceable pollutant gases in compressed gas cylinders (see Section 804.1.2). Additional details of the ARB QAS audit procedures are contained in the Air Monitoring Quality Assurance Manual, Volume V, Audit Procedures for Air Quality Monitoring⁶ available from the ARB and the EPA's Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II: Ambient Air Specific Methods.²

In the procedures used the compressed gas cylinders contain CO as a key gas. The ARB audit van measures the CO concentration in the generated gas is measured by a TECO 48 CO analyzer. The concentrations of the remaining gases are calculated using the dilution ratio (concentration of CO in the generated gas to the concentration of CO in the cylinder) and knowing the certified concentrations of the pollutant gases. The three blended high concentration cylinders contain: CO, NO, SO₂, CH₄; CO, H₂S; and CO, CH₄, C₆H₁₄. In addition, the van carries cylinders of ultrapure zero air, metaxylene, and low level CO (40 - 45 ppm and 6 - 8 ppm CO) cylinders for calibrating the van CO monitor used to measure the CO in the generated gases.

The generated concentrations of pollutant gases are diluted from the cylinder levels using compressed air supplied by an API 701 Zero Air Module pure air

system. The zero air from the pure air system is checked against the certified ultrapure zero air cylinder before each audit to ascertain that clean, dry air is being generated by the pure air system.

An Environics 9100 gas calibration system with an ozone generator and an API 400 ozone analyzer control the mixing of the high concentration pollutant gases with zero air to generate the working audit gases. This system also generates the ozone test atmospheres for auditing the station ozone analyzers (see Section 804.1.5 Ozone Audits Using Ultraviolet Photometry).

The $\text{NO}/\text{NO}_2/\text{NO}_x$ audits are conducted by gas phase titrations (see Section 804.1.3) using the gas calibrator to generate the appropriate concentrations of NO and ozone. The ozone used for the titration is split with part of the flow used to measure the concentration generated and the rest mixed with the audit gas stream to react with NO to form NO_2 .

Once the audit test gas mixtures are generated, the flow is split with part going to the CO analyzer (or ozone analyzer during audits of ozone analyzers) and part going to the monitoring station instruments via a 1/2 inch diameter 150 foot long teflon line with a stainless steel protective braiding.

The results of the audit (both van and station) responses are entered into a database program on a portable or rack mounted computer in the van.

Audits of particulate samplers (see Section 804.1.6) are carried out concurrently with the gas audits and the data also entered into the database program.

At the end of the audit the results of the audit are printed and a copy given to the station operator. In the event that an analyzer fails the performance audit the ARB issues a formal notice, referred to as an AQDA (Air Quality Data Action request), to the operator with a request that the problems be rectified. Once the problems are corrected a re-audit will be conducted to confirm that the corrective actions have solved the problems that lead to the failure.

804.2.2 System Audits

Systems audits evaluate virtually everything about a monitoring program except the performance of the analyzers.² They include an appraisal of the network management, field operations, laboratory operations, data management, quality

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assurance, and reporting. The systems audit should present a clear, complete, and accurate picture of the agency's acquisition of ambient air monitoring data.

A typical system audit consists of a questionnaire requesting extensive information about the monitoring and laboratory practices and procedures of an organization conducting air monitoring and a follow-up on-site evaluation and interview. Appendix 15, Section 2 of the U.S.EPA's QA Manual Volume II² (and included in Appendix D of this manual) contains an extensive system audit questionnaire which can serve as a model for evaluating monitoring programs. The SLAMS/NAMS/PAMS Network Review Guidance⁵ document is also a valuable reference.

After concluding a system audit, a report is required to document and summarize the results. The following format is consistent with guidance offered by the STAPPA/ALAPCO Ad Hoc Air Monitoring Committee. At a minimum the report should contain the following six sections:

- 1) **Executive Summary** - This section summarizes the overall performance of the agency's monitoring program. It should describe any significant conclusions and/or broad recommendations and highlight problem areas needing attention.
- 2) **Introduction** - This section describes the purpose and scope of the audit and identifies audit team members, key agency personnel, and other persons interviewed in the course of the audit. It should also list the agency's facilities visited and inspected (including dates).
- 3) **Audit Results** - This section presents the technical results in sufficient detail to allow a complete understanding of the agency's operations.
 - A. Network design and station siting
 - Network Size - a review of the number of stations and agencies responsible for network operation.
 - Network Design and Siting - describe deficiencies and any planned revisions of the network and probe siting and planned corrective action.
 - Non-Criteria Pollutants - discuss monitoring and quality assurance activities related to monitoring of non-criteria pollutants.
 - B. Resources and Facilities
 - Instruments and Methods - describe any instruments that do not conform to 40 CFR 50, 51, 53, and 58. Also discuss any needed instrument

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replacement above and beyond the nonconforming instruments.

Staff and Facilities - discuss staffing and facilities relative to the ability to conduct the tests and analyses needed to implement SLAMS/NAMS monitoring and quality assurance. Include staff abilities and training, office facilities, laboratory facilities, equipment, and supplies.

C. Data and Data Management

Data Processing and Submittal - discuss staffing and facilities relative to the ability to process and submit the required air quality data. Include an indication of the timeliness of data submittal and the fraction of data which are submitted more than 45 days late.

Data Review - Discuss the agency's performance in meeting the 75% criterion for data completeness and any remedial action (if necessary) to improve data reporting.

Data Correction/Deletion - discuss procedures and protocols used for corrections or deletions made to preliminary data.

Annual Report - comment on the completeness, adequacy, and timeliness of the SLAMS Annual Report.

D. Quality Assurance/Quality Control

Status of Quality Assurance Plan - discuss the status of the agency's Quality Assurance Plan including its approval process and status and the consistency between the agency's standard operating procedures and the QA plan.

Audit Participation - indicate the agency's participation in external audit programs such as the NPAP. Include a discussion of the results of those audits and follow-up by the agency.

Accuracy and Precision - as a goal, the 95% probability limits for precision of all pollutants and TSP accuracy should be less than $\pm 15\%$. At 95% probability limits, the accuracy for all other pollutants should be less than $\pm 20\%$. Using a short narrative and summary table, compare the reporting organization's performance against these goals over the past two years.

- 4) **Discussion** - Discuss the way in which the audit results are being interpreted. The discussion should clearly identify the derivation of audit results which affect both data quality and overall agency operations, and should outline the basis in regulations and guideline documents for the specific, mutually agreed upon, corrective action recommendations.

- 5) **Conclusions and Recommendations** - This section should concentrate on the overall performance of the agency's monitoring program. Any major

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problem areas and their agreed upon corrective actions should be highlighted. Also discuss the homogeneity of the pooling of precision and accuracy data within and between reporting organizations included in the agency's reporting.

- 6) Appendix of Supporting Documents** - This section should contain a copy of all pertinent supporting documents, including, but not limited to the completed questionnaire and any audit finding forms.

804.3 U.S.EPA AUDITS

The U.S.EPA has the authority and responsibility to oversee that the state and local agencies are conducting the appropriate audits. If a state does not have the ability to conduct independent audits of their monitoring program, then the EPA typically will conduct the performance and system audits. The state of California has an independent section that conducts audits and reports the results to the EPA.

All agencies operating SLAMS are required to participate in the EPA's National Performance Audit Program (NPAP). These audits are conducted by either the EPA or other independent auditing section.

For the NPAP audits the EPA prepares blind audit materials and sends them to the auditors who conduct the audit. A typical gas analyzer audit will consist of a cylinder that has been certified by the EPA, a dilution manifold, and instructions detailing the proper settings to use during the audit.

The responses of the monitoring instruments being audited are recorded and submitted to the EPA. The EPA then evaluates the audit performance and returns the results to the auditing organization and the organization operating the monitoring station.

805 INSPECTING AN AIR MONITORING STATION

Inspecting an ambient air monitoring station, in principal, entails evaluation of how the material in much of this manual has been applied. Systems audits, performance audits, site surveys, and conditions reports can all be considered inspections of the monitoring station. In addition, an inspection of a monitoring station should examine the logs, certifications, and calibration records maintained by the station operator.

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In Chapter 200 of this manual the fundamentals of air monitoring are discussed. Such fundamentals as the properties of the pollutant species, their sources and sinks, and transport properties have significant impact on the monitoring program.

For the air monitoring program to generate useful information, the monitoring should be conducted as part of a coherent program (Chapter 300). A number of national and local programs are in existence. An inspection should determine if the monitoring station and network form an appropriate segment of one of these programs.

Once the pollutant to be monitored has been identified and the appropriate program under which it will be monitored has been determined, the appropriate instrumentation must be chosen (Chapter 400). The properties of the pollutant and the program, in addition to local requirements and personal preferences are important factors in selecting the analyzers to be used. Most monitoring agencies have established standardized station configurations that have been demonstrated to function well for situations in that area. Standardized stations also allow for improved economics (for example fewer spare parts are required since all instruments are similar) and more consistency of operational procedures and training. An inspection of a monitoring station should determine if an appropriate match of pollutant, program, and analyzer has been selected.

With the above information determined, the specific station siting and network design (Chapter 600) can be determined. This is an important area where the inspection of monitoring stations can have a significant impact on the data quality. Whereas the above paragraphs refer to topics that determine whether the monitoring station or program is properly initiated, the station siting should be reinspected on a routine basis since the surrounding conditions often change as cities grow or land uses change over time.

Inspections of data handling procedures (Chapter 700), systems audit, and performance audits (Chapter 800), are important in assuring that the data reported by the monitoring organization is accurate and reliable.

Finally, inspections of documentation (Chapter 900) that is required for proper tracking of monitoring station operation is very important. An inspector should examine log books (for example instrument logs and station logs) for completeness and currency.

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806 REFERENCES

1. U.S.EPA, 1994, *Quality Assurance Handbook for Air Pollution Measurement Systems, Volume I: A Field Guide to Environmental Quality Assurance*, EPA/600/R-94/038a.
2. U.S.EPA, 1994, *Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II: Ambient Air Specific Methods*, EPA/600/R-94/038b.
3. *Code of Federal Regulations, Title 40, Part 58*, 1998, U.S. Government Printing Office.
4. *Code of Federal Regulations, Title 40, Part 50*, 1998, U.S. Government Printing Office.
5. U.S.EPA, 1998, *SLAMS/NAMS/PAMS Network Review Guidance*, EPA-454/R-98-003.
6. California Air Resources Board, (1997), *Air Monitoring Quality Assurance, Volume V: Audit Procedures for Air Quality Monitoring*

900 DOCUMENTATION

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A number of reports and logs are needed to document an ambient air monitoring station. Some of this documentation helps assure the user of the quality of the data. Other documentation helps the station operator establish, maintain, and operate the station.

901 SITE INITIATION/TERMINATION REPORT

The site initiation and termination report provides the reasons for beginning or ending monitoring of a pollutant at a site. This form documents not only the initiation or termination of a site, but also changes in pollutants monitored. Typically this report would be accompanied by the Site Identification Report, Pollutant/Project Identification Report, and/or the Probe/Sampler Identification Report. A blank example form is contained in Appendix E and may be copied for use as needed.

902 SITE IDENTIFICATION REPORT

The site identification report provides information about the location of the monitoring station, the surrounding environment, and the types of pollutant sources that may influence the results. Close attention to the location category, dominant influence, and traffic are important in accurately defining the results expected from the station and determining the relationship of the station with other stations in the monitoring network.

The report should be submitted whenever a new site is established or when any parameter of the report is changed. Most commonly, changes in the location category, dominant influence category, traffic type and volume, or the city population instigate changes requiring resubmittal of this form as the area surrounding the monitoring station develop or change land usage. When filling out the form, the geographical coordinates should be entered in either latitude/longitude or UTM units; entries in both units is not needed. When submitting a report for an update at a site, only the site name and number and the items to be changed need to be entered.

When conducting an inspection of a monitoring station it is important to check whether the site identification data reflects the actual monitoring environment. It is very easy for creeping changes to mount up between evaluations. A blank form is contained in Appendix E and may be copied for use as needed.

903 PROBE/SAMPLER IDENTIFICATION REPORT

This report documents the probes and samplers at the monitoring station. The information on this report is integrally related to the monitoring equipment attached to the probe (see next section, Pollutant/Project Identification Report) and the amount of air required by each monitor. A copy of the report is contained in Appendix E and may be copied and used as needed.

This report must be submitted whenever a new probe is installed or a new monitor is attached to a probe (or a monitor exchanged for one with different flow characteristics). It must also be submitted if the probe or inlet sample line is changed for one with different dimensions (i.e. different length, inside diameter, etc.) If a monitor is exchanged for one with the same flow characteristics or the probe/sample line exchanged for one with the same length and dimensions, the report does not need to be submitted. When submitting an update report, only the site name and number and the changing information are required.

One of the more common probe configurations is to use a teflon® sample line (often with a glass cane inlet) to a glass distribution manifold. The sample is then distributed to the individual analyzers via teflon tubing from the manifold to the instruments. A primary consideration in selecting probe materials is that the materials used must be inert to the air and pollutant being measured. Generally glass or teflon is the preferred material. However, since hydrocarbons may be adsorbed and desorbed by teflon, the tubing used for hydrocarbon samples must be either glass or stainless steel. Glass has the disadvantage that it can easily be broken.

Since, even in tubing of nominally inert material, the pollutants may react or be scavenged between the time they enter the inlet and the time they reach the analyzer. Therefore, the probe residence time is important to calculate. The residence time in seconds equals the cross-sectional area of the probe (or tubing) in square millimeters (mm²) times the total length in meters (m) divided by the total flow rate in liters per minute:

$$t = \frac{\pi d^2 \times l \times 0.015}{Q}$$

The residence time must be less than 10 seconds from the inlet to the manifold and less than 20 seconds in total from the inlet to the instrument.

900 DOCUMENTATION

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The inlet, wind sensor, or sampler is considered obstructed if an imaginary line extended 30° up from the horizontal (starting at the inlet) and rotated through 360° intersects any obstruction within 30 m of the inlet.

904 POLLUTANT/PROJECT IDENTIFICATION REPORT

The Pollutant/Project Identification Report documents the pollutants being monitored, equipment used, and the analysis methods employed at a monitoring station. There is space on the report for entering information about two pollutants, if additional pollutants are monitored additional forms need to be completed. In addition, if there is more than one project at the site, separate reports must be submitted for each. For example: if the ARB is conducting parallel monitoring for ozone with an APCD two reports must be submitted: one describing the ARB's project as a special study and another describing the APCD's project as ambient monitoring. A blank form is contained in Appendix E and may be copied for use as needed.

The form must be submitted when monitoring begins or whenever the project, agency, pollutant, collection method, analysis method, reporting units, instrument property number, or the probe/sampler identification code changes. When submitting changes, only the changing information should be entered (other than the identifying site name and site number).

905 SITE SURVEYS AND STATION CONDITIONS

It is very important to routinely review the conditions under which ambient air monitoring is conducted. This can be thought of as having two portions: the site survey, which contains the permanent station information; and the station conditions survey, which documents the transitory conditions at the station such as cleanliness, calibrations, in-line filter changes, etc. Since it documents transitory conditions, the station conditions portion of the survey must be a new and independent evaluation at each visit to the station by the auditors. The site survey portion must be completed in detail when monitoring is initiated and reviewed during station audits. The ARB has combined both functions into a single form (see Appendix E).

The conditions of the monitoring station can be very important to its proper operation. In addition, a well managed, clean, and neat station indicates that the operator has taken care of the station and an independent evaluator can usually

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expect to find fewer instrument problems. A dirty station with a "rat's nest" of tubing behind the instruments is often the first clue that the station hasn't had the care that it should have.

The site survey is an audit tool for confirming the permanent siting and instrument information for a monitoring station. While the Probe/Sampler Report etc. are submitted by the station operators, the site survey is completed by an independent auditor. Information obtained from other reports should be confirmed at the monitoring station by investigation and measurement. Any items that cannot be confirmed or are found to be at odds with the requirements should be noted under Action Items on the first page of the survey and appropriate corrective action initiated to obtain the information or correct the siting.

The survey should describe the monitoring effort (purpose, objective, etc.) at the station and the site description including the latitude, longitude, and topography of the site, the ground cover, and a description of the probe position.

Obstacles to uniform air flow to and around the stations should be described in detail. The severity of the impact of an obstacle on the monitoring results depends on the nature of the obstacle and the pollutant being monitored. The obstacles should be checked carefully since new buildings may be built near the station or trees and bushes may grow to become obstacles.

Local sources, similarly, should be carefully checked for changes. This includes the big obvious sources as well as smaller sources that may be more difficult to see, but can have a significant effect on samples. An example of a small, inconspicuous source may be an emergency generator with its exhaust near the CO and particulate monitors. In addition, very large sources may have an extensive impact area.

One of the most common local sources is traffic. An accurate and current count of traffic on all nearby streets (not just the closest, but all street in the area that may effect the samples collected) is very important for data interpretation. For traffic on state highways in California CALTrans publishes a book of traffic volumes by stretch of highway. In some cases the traffic volume can be obtained from the city or county. If no other count is available, the inspector or station operator may count the number of cars passing. While counting cars gives a short window on the traffic volume and may represent only that short specific time period, it is better than no traffic data.

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The probe and sample distribution system should also be assessed. For each segment (probe, manifold, and tubing to the instrument), the material used and the dimensions should be entered and the segment and total residence time calculated. In general, teflon® or glass are the preferred materials. However, other materials may be better when sampling for some pollutants. For example: since it can adsorb and desorb hydrocarbon pollutants, teflon should not be used for hydrocarbon sampling, only glass or stainless steel probes and sample lines should be used. Also, stainless steel is often the preferred material for particulate matter sampling since it is conductive and will not develop a static charge which can electrostatically remove the particulate matter from the air stream.

Miscellaneous additional information that should be recorded include the cleaning schedule (how often the station and instruments are cleaned), calibrations and the calibration schedule, information about the QA plan used at the station, whether an in-line filter is used and how often it is changed, station temperature control, and whether meteorological parameters are measured in addition to the pollutant concentration measurements.

When properly filled out, the site survey contains a wealth of information that helps determine if the air monitoring station is returning accurate data.

If conditions are found that violate monitoring station siting and maintenance requirements a notice should be issued to the station operator to make the necessary corrections and the station reevaluated after the corrections have been made. In California, the ARB issues a Warning letter for marginal conditions or an Air Quality Data Action (AQDA) request for violations. In some cases, data may have to be corrected or deleted to maintain the integrity of the data for record.

906 STATION LOGS

The Station Log is the master document that records everything that happens at the monitoring station. This includes any alterations of the sampling train such as changes in the probe or monitoring equipment. It also includes records of any conditions in the area around the station that may influence the data such as nearby construction; changes in traffic patterns and flow; special events near the station (parades, fireworks displays, etc.); forest, grassland, or structure fires; etc. Copies of all site reports (Site Surveys, Probe/Sampler Identification Reports, etc.) should be kept with the Station Log.

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The Station Log stays with the monitoring station for the life of the station and is an excellent resource for investigating unusual events and patterns observed in the data returned from the monitoring. During an audit of the monitoring station the Station Log should be examined to be sure it is up to date and accurate.

907 INSTRUMENT LOGS

The Instrument Log stays with the instrument and contains documentation about everything that has happened to a specific piece of equipment. The combination of the Station Log and the Instrument Log should give a complete picture of the history and status of the monitoring station. Both logs should be examined as part of a station audit.

When a new instrument is received a new Instrument Log is initiated. That log will remain with the instrument until the instrument is retired and removed from service. Starting with the acceptance testing, every time routine maintenance and repairs are conducted, the instrument is calibrated, or it is relocated an entry should be made in the log. Whenever an instrument is relocated (including return to the laboratory for repairs, etc.) the ARB requires an Equipment Relocation Notification accompany the instrument. A copy of the Equipment Relocation Notification should be retained in the Instrument Log.

908 CALIBRATION CERTIFICATIONS

All gases and transfer standards used to calibrate and span the instruments at an air monitoring station must be certified. The ARB Standards Laboratory conducts these certifications and issues a Certificate of Analysis (Figure 908.1). Most certifications are good for one year or until the cylinder pressure drops below 300 psi. In addition to gas certifications, PM_{10} flow devices and ozone transfer standards must also be certified.


|  CERTIFICATE OF ANALYSIS CALIFORNIA AIR RESOURCES BOARD TECHNICAL SERVICES DIVISION | |
|--|---|
| COMPRESSED GAS CYLINDER NUMBER | CC12817 |
| ANALYSIS DATE | 1/21/82 CYLINDER PRESSURE: 1900 |
| LOCATION | ARB Modesto 50-568 |
| (AGENCY) (SITE) | OF: SB (SITE NO.) IN N ₂ |
| CERTIFIED CONCENTRATION(S) | 6166/6188 PPM OF CH ₄ /THC GAS |
| | 6289 PPM OF CO GAS |
| | 127.2 PPM OF NO GAS |
| | 62.2 PPM OF SO ₂ GAS |
| CERTIFIED BY: | <i>QAK</i> |
| THIS CERTIFICATION IS NOT VALID IF THE CYLINDER PRESSURE DROPS BELOW 300 PSIG OR AFTER 1/21/83 DATE | |
| RETURN INFORMATION | |
| REASON (✓): EMPTY _____ RECERTIFICATION _____ | |
| OTHER _____ | |
| RETURN DATE: | _____ CYLINDER PRESSURE: _____ |
| 5007-119 1 M DUP - CSF | |

Figure 908.1 Certificate of Analysis

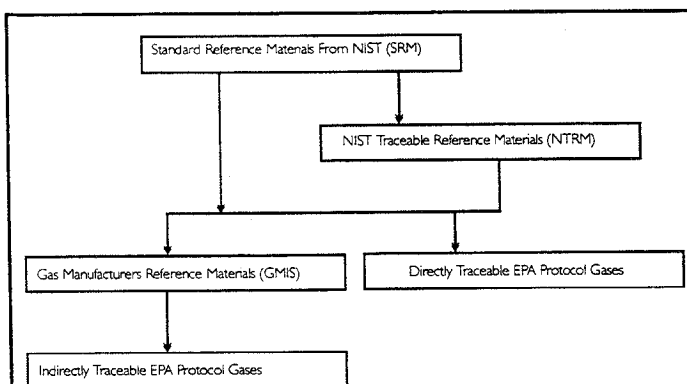
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The gaseous pollutant concentration standards (either permeation devices or cylinders of compressed gases) used to obtain test concentrations for CO, SO₂, NO, and NO₂ must be traceable to either a National Institute of Standards and Technology (NIST) NIST-Traceable Reference Material (NTRM) or a NIST-certified Gas Manufacturer's Internal Standard (GMIS, see Table 908.1). A traceable standard is one that has been compared and certified, either directly or via not more than one intermediate standard, to a primary standard, such as an SRM or NTRM (Figure 908.2).

Table 908.1 Calibration Gas Certifications

| Gas Type | | Certification |
|----------------|---|---|
| SRM | Standard Reference Material | Prepared and sold by NIST |
| NTRM (CRM) | NIST Traceable Reference Material (takes the place of the Certified Reference Material) | Prepared by the gas vendor Referenced directly to a SRM Nominal Concentration within $\pm 1\%$ of an SRM concentration Analyzed after preparation and again 30 days after first analysis Two samples analyzed by an independent laboratory |
| GMIS | Gas Manufacturer's Intermediate Standard | Prepared by the gas vendor Referenced to a SRM or NTRM Nominal concentration 0.3 to 1.3 times the concentration of the SRM or NTRM Must be assayed three times over three months Assays must agree to within 1% Must be recertified every three months |
| Protocol 1 Gas | | Prepared by the gas vendor Referenced to a SRM, NTRM, or GMIS Nominal concentration 0.3 to 1.3 times the concentration of the SRM, NTRM, or GMIS Assays must agree to within 1.5% Reactive gases must be reassayed after seven days |



**Figure 908.2
Calibration Gas
Traceability
Hierarchy**

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Test concentrations for ozone must be obtained using the UV photometric calibration procedure (40 CFR 50, Appendix D) or with a certified ozone transfer standard.

Flow rate measurements such as used to calibrate or audit a PM₁₀ sampler must be made with a transfer standard traceable to an authoritative volume or other applicable standard.

910 REFERENCES

1. California Air Resources Board, 1997, *Air Monitoring Quality Assurance, Volume II: Standard Operating Procedures for Air Quality Monitoring*.
2. *Code of Federal Regulations, Title 40, Part 58*, 1998, U.S. Government Printing Office.

1000 APPENDICES

**Ambient
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**Ambient
Air
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APPENDIX A

ACRONYMS AND ABBREVIATIONS

AIR MONITORING CONSTANTS

BASIC AIR MONITORING DEFINITIONS

Acronyms and Abbreviations

A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U | V | W | X | Y | Z

| | |
|-----------------|--|
| AIM | architectural and industrial maintenance |
| AIRS | Aerometric Information Retrieval System |
| AIRS-AFS | Aerometric Information Retrieval System Facility Subsystem |
| ALAPCO | Association of Local Air Pollution Control Officers |
| AQA | Air Quality Analysis (Workgroup within OTAG) |
| ASCII | American Standard Code for Information Interchange |
| ASCT | area source category |
| auto-GC | automated gas chromatograph |
| BACT | best available control technology |
| BEA | Bureau of Economic Analysis |
| BEIS | Biogenic Emissions Inventory System (1988) |
| BEIS2 | Biogenic Emissions Inventory System (1995) |
| BELD | Biogenic Emissions Landcover Database |
| CAA | Clean Air Act |
| CAAA | Clean Air Act Amendments of 1990 |
| CAPI | Clean Air Power Initiative |
| CARB | California Air Resources Board |
| CASTnet | Clean Air Status and Trends Network (EPA) |
| CB-IV | Carbon Bond-IV |
| CDT | central daylight time |
| CE | control efficiency |
| CEM | continuous emissions monitoring |
| CEQ | Council on Environmental Quality |
| CMSA | consolidated metropolitan statistical area |
| CO | carbon monoxide |
| CO ₂ | carbon dioxide |
| CSUMM | Colorado State University Mesoscale Model |
| CTG | Control Technology Guidelines |
| CTO | Control Technologies and Options (Workgroup within OTAG) |
| CVG | conventional gasoline |
| DOE | U.S. Department of Energy |
| DSM | Demand Side Management |
| ECOS | Environmental Council of the States |
| EDF | Environmental Defense Fund |
| EE | energy efficiency |
| EGAS | Economic Growth Analysis System |
| EI | Emissions Inventory (Workgroup within OTAG) |
| EIA | Energy Information Administration |
| EIS | Environmental Impact Statement |
| EMEFS | Eulerian Model Evaluation and Field Study |

| | |
|-----------------|---|
| EMS-95 | Emissions Modeling System–1995 |
| EPA | U.S. Environmental Protection Agency |
| EPS | Emissions Preprocessor System |
| ERC | emissions reductions credit |
| EST | eastern standard time |
| FCE | future control efficiency |
| FDDA | four-dimensional data assimilation |
| FERC | Federal Energy Regulatory Commission |
| FHWA | Federal Highway Administration |
| GEMAP | Geocoded Emissions Modeling and Projections System |
| g/bhp-h | grams per brake horsepower-hour |
| GDP | gross domestic product |
| g/mi | grams per mile |
| HDV | heavy-duty vehicle |
| hp | horsepower |
| HPMS | Highway Performance Monitoring System |
| HVLP | high-volume, low-pressure (spray equipment) |
| HY-Split | Hybrid Single-Particle Lagrangian Integrated Trajectories model |
| IC | internal combustion |
| ICAC | Institute for Clean Air Companies |
| I/M | inspection and maintenance |
| IPM | Integrated Planning Model |
| IMPROVE | Interagency Monitoring Protected Visual Environments (a collaborative visibility monitoring network operated by EPA and several other agencies) |
| ISI | Implementation Strategies and Issues (Workgroup within OTAG) |
| kg | kilograms |
| km | kilometers |
| km ² | square kilometers |
| LADCO | Lake Michigan Air Directors Consortium |
| LAER | lowest achievable emissions rate |
| lb | pound |
| LDGT | light-duty gasoline truck |
| LDGV | light-duty gasoline vehicle |
| LDT | light-duty truck |
| LDV | light-duty vehicle |
| LEV | low-emission vehicle |
| LMOS | Lake Michigan Ozone Study |
| m | meters |
| MACT | maximum achievable control technology |
| MARAMA | Mid-Atlantic Regional Air Management Association |
| MMBtu | millions of British thermal units |
| MOCA | Modeling Ozone Cooperative |
| mph | miles per hour |
| MSA | metropolitan statistical area |
| MSL | mean sea level |

| | |
|-------------------------|--|
| MTBE | methyl tertiary butyl ether |
| MW | megawatts |
| NAAQS | National Ambient Air Quality Standards |
| NAMS | National Air Monitoring Station |
| NAPAP | National Acid Precipitation Assessment Program |
| NARSTO | North American Regional Strategy for Tropospheric Ozone |
| NCAR | National Center for Atmospheric Research |
| NEEDS | National Electric Energy Data System |
| NEI | National Emission Inventory |
| NERC | North American Electric Reliability Council |
| NET | National Emission Trends |
| NESCAUM | Northeast States for Coordinated Air Use Management |
| NMHC | non-methane hydrocarbon |
| NGM | nested grid model |
| NH ₃ | ammonia |
| NLEV | National Low-Emission Vehicle Program |
| NO | nitric oxide |
| NOAA | National Oceanic and Atmospheric Administration |
| NO _x | nitrogen oxides |
| NO _y | totally reactive nitrogen |
| NO _z | products of NO _x oxidation |
| NO ₂ | nitrogen dioxide |
| NSPS | New Source Performance Standards |
| NSR | new source review |
| NWS | National Weather Service |
| O ₃ | ozone |
| OAQPS | Office of Air Quality Planning and Standards |
| OBD | on-board diagnostic |
| OMS | Office of Mobile Sources |
| OMTR | Open Market Trading Rule |
| OTAG | Ozone Transport Assessment Group |
| OTC | Ozone Transport Commission |
| OTC NO _x MOU | Ozone Transport Commission NO _x Memorandum of Understanding |
| OTR | Ozone Transport Region |
| PAMS | Photochemical Analysis Monitoring System |
| PFC | progressive flow control |
| PiG | Plume-in-Grid |
| PM-10 | particulate matter with an aerodynamic diameter less than or equal to a nominal 10 micrometers |
| PIO | public information office |
| ppb | parts per billion |
| ppbC | parts per billion measurement based on carbon content |
| ppm | parts per million |
| psi | pounds per square inch |

| | |
|-----------------|---|
| QA | quality assurance |
| r^2 | correlation coefficient |
| RACT | reasonably available control technology |
| RAMS | Regional Atmospheric Modeling System |
| RASS | radar acoustic sounding systems |
| reg/neg | regulation/negotiation |
| RFG | reformulated gasoline |
| RFP | reasonable further progress |
| r/min | revolutions per minute |
| ROG | reactive organic gases |
| ROM | regional oxidant modeling |
| ROP | rate of progress |
| RUSM | Regional and Urban Scale Modeling (Workgroup within OTAG) |
| RVP | Reid vapor pressure |
| SAIMM | Systems Applications International Mesoscale Model |
| SCC | source classification code |
| SCION | Southeastern Consortium Intermediate Oxidant Network (ambient monitoring network used as part of the Southern Oxidants Study) |
| SCF | source conversion factor |
| SCR | selective catalytic reduction |
| SIC | standard industrial classification (code) |
| SIP | State Implementation Plan |
| SLAMS | State/Local Air Monitoring Station |
| SNCR | selective noncatalytic reduction |
| SO ₂ | sulfur dioxide |
| SOS | Southern Oxidants Study |
| STAPPA | State and Territorial Air Pollution Program Administrators |
| SUPROXA | Super Regional Oxidant A (modeling domain) |
| SPECIATE | EPA's Air Emissions Species Database |
| STID/CYID | state ID/county ID |
| TDL | tape data library |
| T/I | Trading/Incentives (Workgroup within OTAG) |
| TLEV | transitional low-emission vehicle |
| TOG | total organic gas |
| TOMS | Total Ozone Mapping Spectrometer |
| TPD | tons per day |
| TPY | tons per year |
| TSDF | treatment, storage, and disposal facility |
| TTN | Technology Transfer Network |
| TVA | Tennessee Valley Authority |
| UAM-V | Urban Airshed Model, Version V |
| UARG | Utility Air Regulatory Group |
| USGS | U.S. Geological Survey |
| UTM | Universal Transverse Mercator |
| UV | ultraviolet |

| | |
|------|---|
| VMT | vehicle miles traveled |
| VNR | video news release |
| VOC | volatile organic compound |
| WDNR | Wisconsin Department of Natural Resources |

Constants

| | |
|---------------------------|---|
| Avogadro's Number | 6.02×10^{23} atoms per gram-atom |
| Faraday constant | 9.65×10^4 Coulombs per mole |
| 1 g-mol | 22.4 l ideal gas at standard temperature and pressure (STP: 0°C, 1 atm) |
| 1 lb-mol | 359 ft ³ ideal gas at STP (32°F, 1 atm) |
| ln 10 | 2.3026 |
| Natural log base <i>e</i> | 2.7183 |
| Plank's constant | 6.62×10^{-27} erg s |
| Speed of light | 3.0×10^{10} cm/s |
| Speed of sound | 344 m/s in air (20°C, 1 atm) |
| Gas Constant (R) | depends on units of pressure, volume, moles, and temperature used. For example, from the following table, if units of cm ³ , Kelvins, gram moles, and atmospheres are used the value of R is 82.05 |

| Volume | Temp | Moles | Pressure | | | | | | |
|------------|------|-------|----------|---------|--------------------|--------------------|--------------------|--------------------|--------------------|
| | | | Atm. | psia | mm Hg | cm Hg | in. Hg | in. H2O | ft. H2O |
| cubic feet | K | gm | 0.0029 | 0.0426 | 2.2 | 0.22 | 0.0867 | 1.18 | 0.0982 |
| | | lb | 1.31 | 19.31 | 999 | 99.9 | 39.3 | 535 | 44.6 |
| | R | gm | 0.00161 | 0.02366 | 1.22 | 0.122 | 0.0482 | 0.655 | 0.0546 |
| | | lb | 0.73 | 10.73 | 555 | 55.5 | 21.8 | 297 | 24.8 |
| cubic cm | K | gm | 82.05 | 1206 | 62400 | 6240 | 2450 | 33400 | 2780 |
| | | lb | 37200 | 547000 | 2.83×10^7 | 2.83×10^6 | 1.11×10^6 | 1.51×10^7 | 1.26×10^6 |
| | R | gm | 45.6 | 670 | 34600 | 3460 | 1360 | 18500 | 1550 |
| | | lb | 20700 | 304000 | 1.57×10^7 | 1.57×10^6 | 619000 | 8.41×10^6 | 701000 |
| liters | K | gm | 0.08505 | 1.206 | 62.4 | 6.24 | 2.45 | 33.4 | 2.78 |
| | | lb | 37.2 | 547 | 28300 | 2830 | 1113 | 15140 | 1262 |
| | R | gm | 0.0456 | 0.67 | 34.6 | 3.46 | 1.36 | 18.5 | 1.55 |
| | | lb | 20.7 | 304 | 15700 | 1570 | 6.19 | 8410 | 701 |

Common Pollutant and Atmospheric Molecules

| Molecule | Symbol | Molecular Weight |
|-----------------------|------------------|------------------|
| Oxygen | O ₂ | 32 |
| Nitrogen | N ₂ | 28 |
| Water | H ₂ O | 18 |
| Carbon Dioxide | CO ₂ | 44 |
| Carbon Monoxide | CO | 28 |
| Sulfur Dioxide | SO ₂ | 64 |
| Nitric Oxide | NO | 30 |
| Nitrogen Dioxide | NO ₂ | 46 |
| Air (dry @20°C) | -- | 28.9 |
| Air (saturated @20°C) | -- | 28.7 |

Standard Conditions

International Scientific Standard Conditions

| Pressure | Temperature |
|-----------------------------|-------------|
| 760 mm Hg | 0°C |
| 101.3 kPa | 273 K |
| 29.92 in. Hg | 460 R |
| 406.79 in. H ₂ O | |
| 14.696 psia | |

EPA Stationary Source Reference Methods

| Pressure | Temperature |
|--------------|-------------|
| 760 mm Hg | 20°C, 293 K |
| 29.92 in. Hg | 68°F |

EPA Ambient Methods Standard Conditions

| Pressure | Temperature |
|--------------|-------------|
| 760 mm Hg | 25°C |
| 101.3 kPa | 298 K |
| 29.92 in. Hg | |

US Gas Industry Standard Conditions

| Pressure | Temperature |
|--------------|-------------|
| 30.00 in. Hg | 60°F |
| | 520 R |

Conversion Expressions

Temperature

| | |
|----------------------------|-----------------|
| $K = ^\circ C + 273.15$ | Kelvins |
| $R = ^\circ F + 459.4$ | Degrees Rankine |
| $EC = 5/9(^{\circ}F - 32)$ | |
| $EF = 9/5^{\circ}C + 32$ | |

Gas Concentration Units

To convert ppm to milligrams per cubic meter (mg/m³) at a set of standard conditions:

$$\frac{\text{mg}}{\text{dscm}} = \frac{\text{ppm} \times \text{MW}}{22.414 \times (T_{\text{std}} / 273.15)}$$

At EPA standard conditions:

| |
|---|
| 100 ppm CO = 116 mg/m ³ |
| 100 ppm HCl = 163 mg/m ³ |
| 100 ppm NO ₂ = 191 mg/m ³ |
| 100 ppm SO ₂ = 266 mg/m ³ |

Conversion Factors

Energy

$$1 \text{ BTU} = 1055 \text{ J}$$

$$1 \text{ BTU/hr} = 0.293 \text{ MW}$$

Density

$$13.6 \text{ in. H}_2\text{O} = 1 \text{ in. Hg}$$

$$13.6 \text{ mm H}_2\text{O} = 1 \text{ mm Hg}$$

Length

$$1 \text{ in.} = 2.54 \text{ cm}$$

$$1 \text{ ft} = 0.305 \text{ m}$$

Volume

$$1 \text{ ft}^3 = 0.0283 \text{ m}^3 = 28.32 \text{ liters} = 28,320 \text{ cm}^3$$

$$1 \text{ m}^3 = 35.31 \text{ ft}^3$$

$$1 \text{ in}^3 = 16.4 \text{ cm}^3$$

Velocity

$$1 \text{ ft/min} = 0.508 \text{ cm/s}$$

$$1 \text{ ft/s} = 30.5 \text{ cm/s}$$

Flow Rate

$$1 \text{ m}^3/\text{s} = 2120 \text{ ft}^3/\text{min}$$

$$1 \text{ ft}^3/\text{min} = 28.3 \text{ liters/min}$$

$$1 \text{ ft}^3/\text{hr} = 0.47 \text{ liters/min}$$

Mass

$$1 \text{ g} = 0.0022 \text{ lb}$$

$$1 \text{ lb} = 453.6 \text{ g}$$

Mass Per Unit Volume

$$1 \text{ g/m}^3 = 0.0283 \text{ g/ft}^3$$

$$1 \text{ lb/ft}^3 = 16.02 \text{ kg/m}^3$$

$$1 \text{ grain/ft}^3 = 2.29 \text{ g/m}^3$$

$$1 \text{ mg/m}^3 = 6.23 \times 10^{-8} \text{ lb/ft}^3$$

Pressure

$$1 \text{ atm} = 1.01325 \times 10^5 \text{ Pa} = 14.696 \text{ lb/in.}^2$$

$$= 760 \text{ torr} = 760 \text{ mm Hg}$$

$$= 1040 \text{ cm H}_2\text{O} = 407.2 \text{ in. H}_2\text{O}$$

Power

$$1 \text{ BTU/hr} = 0.2931 \text{ W}$$

$$1 \text{ kW} = 3413 \text{ BTU/hr}$$

Emissions

$$1 \text{ ng/J} = 2.326 \times 10^{-3} \text{ lb/10}^6\text{BTU}$$

$$1 \text{ lb/10}^6\text{BTU} = 430 \text{ ng/J}$$

BASIC AIR MONITORING DEFINITIONS

COURSE NO. 222

THE FOLLOWING DEFINITIONS ARE BEING PRESENTED TO CLARIFY SOME OF THE TERMS AND DESCRIPTIONS WHICH WILL BE USED IN THE PRESENTATION OF THIS CLASS. SOME TERMS HAVE BEEN MODIFIED/SHORTENED TO MORE CLOSELY RELATE TO THEIR APPLICATION TO AIR MONITORING INSTRUMENTATION.

DEFINITIONS

| | |
|---------------------|--|
| ABSORPTION | (1) The process of transferring one or more gaseous components into a liquid or solid medium in which they dissolve; (2) A taking in and not reflecting. |
| ACCURACY | The degree of agreement between a measured value and the true value, usually expressed at +/-% of full scale. |
| ADSORPTION | The phenomenon by which gases are attracted, concentrated and retained at a boundary surface. |
| AIR POLLUTION | The presence of unwanted material in the air. The term "unwanted material" here refers to material concentrations present for a sufficient time and under circumstances to interfere significantly with comfort, health, or welfare of persons, or with the full use and enjoyment of property. |
| AMPLIFIER | A device that increases the magnitude of a varying quantity, such as an electrical voltage. The amount that is increased can be controlled. |
| ATMOSPHERE, THE | The whole mass of air surrounding the earth and being composed largely of oxygen and nitrogen. |
| ATMOSPHERE, AN | A specific gaseous mass, occurring either naturally or artificially containing any number of constituents and in any proportion. |
| BAROMETRIC PRESSURE | Barometric and atmospheric pressure are synonymous. These pressures are measured with a barometer and are usually expressed in inches or millimeter of mercury. <u>Standard barometric pressure is the average atmosphere pressure at sea level 45° north latitude at 35°F and is the equivalent to a pressure of 14.606 grams-force per square centimeter exerted at the base of a column of mercury 760 mm high.</u> |
| BEER-LAMBERT LAW | An exponential decay law which is used to calculate the intensity of light that has traveled a certain distance through an absorbing media (sample). |
| CALIBRATION | The act of determining, checking, or rectifying the graduation of any instrument giving quantitative measurements. |

| | |
|-----------------------------------|---|
| CALIBRATION STANDARDS | A substance or material with properties believed to be known with sufficient accuracy to permit its use to evaluate the same property of another. |
| CALIBRATOR | A system for diluting high concentrations with pure air to produce (DILUTION SYSTEMS) precise mixes of ozone and other gases. |
| CARBON MONOXIDE | A colorless, odorless, highly poisonous gas. Breathing one volume (CO) of it mixed with 800 volumes of air for one half hour can be fatal. In general, carbon monoxide is formed whenever carbon is burned in limited supply of oxygen. |
| CHEMILUMINESCENCE | Light produced by chemical reaction between ozone and NO. |
| CHROMATOGRAPHIC COLUMN | A small thin tube containing material which retards the movement (GAS) of different compounds based on their molecular structure. The column is a critical part of an instrument used in performing chromatographic separation of samples. |
| CHROMATOGRAPHY | The process of separating constituents of gases by permitting a solution of a mixture to flow through a separation device (chromatographic column). The constituents exit the column at different characteristic retention times. |
| CRITICAL ORIFICE | If the pressure drop across an orifice is increased until the downstream pressure is equal to approximately 0.53 times the upstream pressure (for air and some other gases), the velocity of the constriction will become acoustic or sonic. Orifices used in this manner are called critical orifices. |
| CYLINDER (PRESSURIZED SYSTEMS) | Cylinders containing a pollutant gas are prepared by adding a known volume of pollutant gas and then pressurizing the cylinder with a diluent gas. The gas is then of a known concentration and can be used for calibration purposes. |
| DATA LOGGING | An intermediate data collection and storage system for air monitoring data. Raw data from analyzers are in analog direct current voltages (DC) which in turn is proportional to the measured gas concentrations. These voltages become a permanent record accurately reflecting the results of continuous air sampling and are usually placed directly into strip chart recorders. This DC data may also be placed into an electronic data logger which will store the information and subsequently provide the user with more versatile information such as: averaging time, trends, deviations from previously established limits, gas comparison and correction factors. |
| DICHOTOMOUS SAMPLER | A sampler which is used to collect the coarse and fine fractions of PM ₁₀ . |

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| DIURNAL | The term means recurring daily. Applied to (variations in concentrations of) air contaminants, diurnal indicates variation following a distinctive pattern and recurring from day to day. |
| DISPERSION | The most general term for a system consisting of particulate matter suspended in air or other gases. |
| EFFICIENCY | The ratio of attained performance to absolute performance. |
| ELECTROMAGNETIC RADIATION | Radiation energy created by the acceleration of an electron or other charged particle. This energy travels through space or matter in the form of transverse waves depending on the wavelength, exists as visible light, radio waves, X-rays, infrared (heat), or gamma rays. |
| EMISSIONS | The total of substances discharged into the air from a vent, or other discrete source. |
| EQUILIBRIUM | A state of rest due to the action of forces that counteract each other. |
| EQUIVALENT METHOD | A method of sampling and analyzing the ambient air for an air pollutant that has been designated as equivalent to reference method in the Code of Federal regulations Title 40, Part 53. |
| FINE FRACTION | Those constituents of PM_{10} that are nominally less than 2.5 micrometers in diameter. |
| FLOWMETER | An instrument for measuring the rate of flow of a fluid moving through a tubing. The instrument is calibrated, to give volume or mass rate of flow. |
| GAS | One of the three states of aggregation of matter, having neither independent shape nor volume and tending to expand indefinitely. |
| GAS FILTER CORRELATION (GFC) | A highly specific light probe is created by causing a beam of infrared light of narrow spectral bandwidth to be intercepted by a rotating wheel containing two different entrapped gases; Carbon monoxide and nitrogen. |
| HIGH VOLUME SAMPLER | An instrument which forces a large volume air sample through a filter thus depositing any particulates on the filter. |
| HYDROCARBON | Any compound containing only hydrogen and carbon. Many of these compounds, when chemically reacted with nitrogen oxides and sunlight, produce ozone. |
| IMPACTION | A forcible contact of particles of matter, a term often used synonymously with impingement. |
| IMPACTOR | A sampling device that employs the principle of impaction (impingement). |

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| IMPINGEMENT | The act of bringing matter forcibly in contact. As used in air sampling, impingement refers to the process for the collection of particulate matter in which the gas being sampled is directed forcibly against a surface. |
| LIGHT (VISIBLE) | Electromagnetic radiation to which the organs of sight react, ranging in wavelength from about 4,000 to 7,000 Angstrom units and propagated at a speed of 186,300 miles per second. |
| LITER | Metric system. A unit of capacity equal to the volume of one kilogram of water at its maximum density or very nearly one cubic decimeter, and equivalent to 1.0567 U.S. liquid quarts. |
| MASS FLOW CONTROLLER | The flow controller is a self-contained, closed-loop control system which measures the mass rate of gaseous flow through the instrument, compares this with an externally commanded flow rate, and adjusts the valve to control the flow to the commanded level |
| MICROMETER (MICRON) | (1) One millionth of a meter; (2) A particle having a diameter between .01 and .001 millimeter. |
| MULTIPOINT CALIBRATION | The process of analyzing a series of standards at different concentrations to ensure that the particular instrument responds linearly to different concentration analysis. |
| NITRIC OXIDE (NO) | A general term pertaining to compounds which contain one nitrogen and one oxygen atom. Nitrogen oxides are typically created during combustion processes and are major contributors to smog formation and acid deposition. These compounds, when chemically reacted with hydrocarbon and sunlight produce ozone. |
| NON DISPERSIVE INFRARED | NDIR analyzers are based on the infrared absorption of a gaseous RADIATION (NDIR) pollutant. They are termed non dispersive analyzers because they use no prisms or grating to disperse the infrared radiation. A narrow band filter that absorbs all frequencies except the one of interest is used. |
| OPTICAL FILTER | A device that lets through, or reflects certain wavelengths ONLY. |
| OZONE (O ₃) | (Physical) A colorless gas, an allotropic form of oxygen, having a peculiar odor like that of chlorine and extreme chemical activity. (Chemical) Powerful oxidizing agent, converts NO to N ₂ O ₃ (Produced) 1. <u>Electrostatic</u> - Dry air is brought into contact with an electrically charged field. 2. <u>Ultraviolet rays</u> - A current of air is subjected to influence of the rays from a mercury vapor lamp. |

PHOTOMETER

Consists of a source of wavelength specific light, a closed container, or "chamber" to confine the gas being monitored, a light detector or transducer to convert light to electrical energy and suitable electronics to manipulate electrical information so the content may be displayed in appropriate concentration units.

PM₁₀

Atmospheric particles, solid and liquid, except uncombined water as measured by a PM₁₀ sampler which collects 50 percent of all particles of 10 micrometer aerodynamic diameter and which collects a declining fraction of particles as their diameter decreases. Similar to the lung deposition of the human being.

PRECISION

The degree of mutual agreement characteristics of independent measurements as the result of repeated application of the process under specified conditions. It is concerned with the closeness of results.

PRECURSOR

A substance that precedes, and is the source of another substance.

PRIMARY STANDARD

A standard that has the highest possible degree of accuracy obtainable.

PROBE

A tube used for sampling at a distance from the actual collection or measuring device.

PURE AIR GENERATOR (ZERO AIR)

Air that is used as a gas diluent and as such must be absent of any of the pollutants which are to be reduced to lower concentration.

RAW DATA

Preliminary data obtained from a measurement process.

RE-ENTRAINMENT

A situation where particles are re-suspended in the air.

REFERENCE METHOD

A method of sampling and analyzing the ambient air for air pollutant that is specified as a reference method in the Code Federal Regulations Title 40, Part 50 and Part 53.

REPEATABILITY

The ability of an instrument or device to produce the same results when repeatedly tested under identical conditions.

ROTAMETER

A device, for measuring rate of fluid flow. It consists of a tapered tube having a circular cross-section, and containing a float that is free to move in a vertical path to a height dependent upon the rate of fluid flow upward through the tube.

ROVER

A mobile monitor station.

SAMPLING

A process consisting of the withdrawal or isolation of a fractional part of a whole. In air or gas analysis, the separation of a portion of ambient atmosphere with or without the simultaneous isolation of selected components.

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| SCRUBBER | A type of apparatus used in sampling and in gas cleaning in which gas is passed through a space containing wetted materials which will result in a sorption action to remove specific gases. |
| SELECTIVITY | Capability of instrumentation to respond to a desired substances or constituent and not to others. |
| SENSITIVITY | Capability of instrumentation to discriminate between samples having differing concentrations. |
| SIZE SELECTIVE INLET (SSI) | An inlet which is designed to pass PM_{10} through the device when the airstream is flowing through a specified speed. Larger particles are removed from the air stream. |
| SORBENT | A liquid or solid medium in or upon which materials are retained by absorption or adsorption. |
| SORPTION | A process consisting of either absorption or adsorption |
| STANDARD | A substance or material with properties believed to be known with sufficient accuracy to permit its use to evaluate the same property of another. |
| STANDARD CONDITIONS FOR | To be able to compare gas sampling data collected under varying. |
| ATMOSPHERIC SAMPLING | conditions, all gas volumes must be corrected to a set of predetermined "standard" conditions. For atmospheric or ambient sampling, these conditions are: 25°C or 298K at 760 mm Hg. Standard conditions for temperature and pressure are abbreviated STP. |
| THERMISTOR | A semiconductor whose resistance changes due to heat variations in a predictable manner and is often used as a thermal detector. |
| THERMOCOUPLE | A device that produces an electric potential from the heating of a junction of two dissimilar metals. widely used as a thermal detector. |
| TRANSDUCER | A transducer is a device that is activated by power from one system and supplies power in some form to the other. Electrical pressure transducers converts mechanical displacement into an electric signal. |
| TRANSFER STANDARD | A standard that can be traced to a higher standard, having been certified against that higher standard. A transfer standard is normally a rugged measurement system that is stable and repeatable and is used to calibrate instruments in remote locations. It is used because the standard it is referenced to cannot be easily transported or is fragile. |
| TRAVERSE | To pass over, across, or through. |

ULTRAVIOLET (UV) DETECTION

Detectors (photodiodes) used in scientific instruments are "solar blind" cesium telluride diodes with selective bandwidth. Ultraviolet light striking the cesium telluride material results in proportional changes of conductivity. With a known voltage applied, the photo diode converts light to current through the photoelectric effect and the output current is incident light.

ULTRAVIOLET (UV) LIGHT

That part of the electromagnetic radiation spectrum between visible light and X-rays. Its wavelengths are longer than those of X-rays, but shorter than those of ordinary light. The UV spectrum is from 400 to 4nm. Ultraviolet radiation obeys the laws of optical reflection and refraction. It is transmitted easily through quartz, fluoride and distilled water. However, it is absorbed by many substances that are transparent to visible light. Ordinary glass, for example is opaque to wavelengths shorter than 300nm.

ULTRAVIOLET (UV) PHOTOMETRY

The visible and UV light absorption of molecules are associated with electronic energy level transitions. Instruments making use of UV absorption of pollutants measure the absorption at a specific wavelength that can be related to the concentration of the pollutant by Beer's law.

ULTRAVIOLET (UV) SOURCE

Most UV sources use a low pressure cold cathode mercury vapor tube. The lamp has a bulb of quartz (transparent to ultraviolet rays). The resulting UV radiation is not symmetrical around the tube, but has a distinctive figure "8" pattern.

ZERO AIR

See pure air

§ 58.1 Definitions.

As used in this part, all terms not defined herein have the meaning given them in the Act:

(a) **Act** means the Clean Air Act as amended (42 U.S.C. 7401, et seq.).

(b) **SLAMS** means State or Local Air Monitoring Station(s). The SLAMS make up the ambient air quality monitoring network which is required by § 58.20 to be provided for in the State's implementation plan. This definition places no restrictions on the use of the physical structure or facility housing the SLAMS. Any combination of SLAMS and any other monitors (Special Purpose, NAMS, PSD) may occupy the same facility or structure without affecting the respective definitions of those monitoring station.

(c) **NAMS** means National Air Monitoring Station(s). Collectively the NAMS are a subset of the SLAMS ambient air quality monitoring network.

(d) **PSD station** means any station operated for the purpose of establishing the effect on air quality of the emissions from a proposed source for purposes of prevention of significant deterioration as required by § 51.24(n) of part 51 of this chapter.

(e) **SO₂** means sulfur dioxide.

(f) **NO₂** means nitrogen dioxide. **NO** means nitrogen oxide. **NO_x** means oxides of nitrogen and is defined as the sum of the concentrations of NO₂ and NO.

(g) **CO** means carbon monoxide.

(h) **O₃** means ozone.

(i) **Plan** means an implementation plan, approved or promulgated pursuant to section 110 of the Clean Air Act.

(j) **Administrator** means the Administrator of the Environmental Protection Agency (EPA) or his or her authorized representative.

(k) **Regional Administrator** means the Administrator of one of the ten EPA Regional Offices or his or her authorized representative.

(l) **State agency** means the air pollution control agency primarily responsible for development and implementation of a plan under the Act.

(m) **Local agency** means any local government agency, other than the State agency, which is charged with the responsibility for carrying out a portion of the plan.

(n) **Indian Reservation** means any Federally recognized reservation established by treaty, agreement, executive order, or act of Congress.

(o) **Indian Governing Body** means the governing body of any tribe, band, or group of Indians subject to the jurisdiction of the United States and recognized by the United States as possessing power of self-government.

(p) **Aerometric Information Retrieval System (AIRS)-Air Quality Subsystem (AQS)** is EPA's computerized system for storing and reporting of information relating to ambient air quality data.

(q) **Storage and Retrieval of Aerometric Data (SAROAD)** system is a computerized system which stores and reports information relating to ambient air quality. The SAROAD system has been replaced with the AIRS-AQS system; however, the SAROAD data reporting format continues to be used by some States and local air pollution agencies as an interface to AIRS on an interim basis.

(r) **SAROAD site identification form** is one of the several forms in the SAROAD system. It is the form which provides a complete description of the site (and its surroundings) of an ambient air quality monitoring station.

(s) **Traceable** means that a local standard has been compared and certified, either directly or via not more than one intermediate standard, to a primary standard such as a National Institute of Standards and Technology Standard Reference Material (NIST SRM) or a USEPA/NIST-approved Certified Reference Material (CRM).

(t) **Urban area population** means the population defined in the most recent decennial U.S. Census of Population Report.

(u) **TSP** (total suspended particulates) means particulate matter as measured by the method described in appendix B of part 50 of this chapter,

(v) **PM10** means particulate matter with an aerodynamic diameter less than or equal to a nominal 10 micrometers as measured by a reference method based on appendix J of part 50 of this chapter and designated in accordance with part 53 of this chapter or by an equivalent method designated in accordance with part 53 of this chapter.

(w) **Pb** means lead.

(x) **PAMS** means Photochemical Assessment Monitoring Stations.

(y) **VOC** means volatile organic compounds.

(z) **Meteorological measurements** means measurements of wind speed, wind direction, barometric pressure, temperature, relative humidity, and solar radiation.

[44 FR 27571, May 10, 1979, as amended at 48 FR 2529, Jan. 20, 1983; 51 FR 9586, Mar. 19, 1986; 52 FR 24739, July 1, 1987]

Air Quality Glossary



acid deposition:

air pollution produced when acid chemicals are incorporated into rain, snow, fog, or mist. *See also* acidic pollution in the parks

adverse impact:

a determination that an air-quality related value is likely to be degraded within a Class I area. *See also* Clean Air Act

Aerometric Information Retrieval System (AIRS):

a computer-based repository of US air pollution information administered by the EP A Office of Air Quality Planning and Standards

AIRWeb:

Air Resources Web, a US National Park-focused air quality information retrieval system developed by the Air Resources Division of the National Park Service

aerosol:

a suspension of microscopic solid or liquid particles in air. *See also* haze, particulate matter.

air pollutant:

an unwanted chemical or other material found in the air. *See also* air pollution.

air pollution:

degradation of air quality resulting from unwanted chemicals or other materials occurring in the air. *See also* air pollutant.

air quality:

(in context of the national parks:) the properties and degree of purity of air to which people and natural and heritage resources are exposed

air pollution control permitting process:

process by which facilities are permitted to emit specified types and quantities of air pollutants

air quality related values (AQRVs):

values including visibility, flora, fauna, cultural and historical resources, odor, soil, water, and virtually all resources that are dependent upon and affected by air quality. "These values include visibility and those scenic, cultural, biological, and recreation resources of an area that are affected by air quality" (43 Fed. Reg. 15016).

ambient air:

air that is accessible to the public

attainment area:

a geographic area in which levels of a criteria air pollutant meet the health-based National Ambient Air Quality Standard for that specific pollutant

Best Available Control Technology (BACT):

an emission limitation based on the maximum degree of reduction for each pollutant, that must be applied by sources subject to the Prevention of Significant Deterioration program

biological effects:

ecological studies to determine the nature or extent of air pollution injury to biological systems. *See also* biological effects pages.

camera:

device for recording visual range on film

carbon monoxide:

a criteria air pollutant that is a colorless, odorless, poisonous gas produced by incomplete combustion; particularly, incomplete burning of carbon-based fuels e.g. gasoline, oil, and wood

class I:

areas of the country set aside under the Clean Air Act to receive the most stringent degree of air quality protection. *See also class II.*

class II:

areas of the country protected under the Clean Air Act, but identified for somewhat less stringent protection from air pollution damage than class I, except in specified cases

Clean Air Act:

Originally passed in 1963, our current national air pollution control program is based on the 1970 version of the law. Substantial revisions were made by the 1990 Clean Air Act Amendments. *See also Clean Air Act pages.*

clean fuels:

low-pollution fuels that can replace ordinary gasoline, including gasohol, and natural and LP gas

continuous sampling device:

an air analyzer that measures air quality components continuously. *See also monitoring, integrated sampling device.*

criteria:

(in the context of criteria pollutants;) information on health and/or environmental effects of pollution

criteria air pollutant:

a group of very common air pollutants regulated by EPA on the basis of criteria, and for which a National Ambient Air Quality Standard is established (SO₂, NO₂, PM₁₀, Pb, CO, O₃). *See also EPA's NAAQS page.*

dose-response:

the relationship between the dose of a pollutant and its effect on a biological system

emissions:

release of pollutants into the air from a source

enforcement:

legal methods used by EPA, state, and local governments to make polluters obey the Clean Air Act. In the absence of enforcement, citizens can sue EPA or the states to obtain action, and can also sue violating sources apart from any action EPA or state or local governments have taken.

Environmental Protection Agency (EPA):

the federal agency responsible for regulating air quality. *See also EPA web site.*

fine particle:

particulate matter less than 2.5 microns in diameter

Gulf of Maine Oxidant Study (GOMOS):

a study to investigate the sources and transport of pollutants contributing to ozone formation

hazardous air pollutants (HAP):

airborne chemicals that cause serious health and environmental effects

haze (hazy):

a visual phenomenon resulting from scattering of light in a volume of aerosols. In the context of air pollution, haze is caused in large part by man-made< A HREF = "#ap1"> air pollutants. *See also regional haze and "Visibility on the Colorado Plateau"*

impairment:

the degree to which a scenic view or distance of clear visibility is degraded by man-made pollutants

IMPROVE:

Interagency Monitoring of Protected Visual Environments, a collaborative monitoring program to

establish present visibility levels and trends, and to identify sources of man-made impairment. *See also IMPROVE Newsletter.*

integrated sampling device:

an air sampling device that allows estimation of air quality components over a period of time (e.g. two weeks) through laboratory analysis of the sampler's medium

major source:

a stationary facility that emits a regulated pollutant in an amount exceeding the threshold level (100 or 250 tons per year, depending on the type of facility). *See also source.*

mobile sources:

moving objects that release regulated air pollutants, e.g. cars, trucks, buses, planes, trains, motorcycles, and gas-powered lawn mowers. *See also source; stationary source.*

monitoring:

measurement of air pollution. *See also continuous sampling device, integrated sampling device.*

National Ambient Air Quality Standards (NAAQS):

permissible levels of criteria air pollutants established to protect public health and welfare. *See also EPA's NAAQS page.*

nitrogen oxides:

a criteria air pollutant, compounds NO, NO₂, NO₃, N₂O₅, alkyl nitrates, etc. *See also NO_x and NO_y.*

nonattainment area:

a geographic area in which the level of a criteria air pollutant is higher than the level allowed by the federal standards. *See also EPA's nonattainment page.*

North Atlantic Regional Experiment (NARE):

a study to assess the contribution of continental air pollution to the North Atlantic Ocean

NO_x:

the sum of NO + NO₂. *See also nitrogen oxides, NO_y.*

NO_y:

the sum of all oxidized nitrogen species, i.e. NO, NO₂, NO₃, HNO₃, N₂O₅, alkyl nitrates, PAN, etc. Does not include NH₃ or N₂O. *See also nitrogen oxides, NO_x.*

nephelometer:

an optical instrument that measures the scattering coefficient of ambient air

organic compounds:

chemicals that contain the element carbon

ozone:

a gas similar to oxygen that is a criteria air pollutant and a major constituent of smog. *See also reactive organic compounds; volatile organic compounds.*

particle sampler:

an instrument to measure particulate matter in ambient air

particulate matter

dust, soot, other tiny bits of solid materials that are released into and move around in the air. *See also fine particle, PM₁₀, Visibility Research Program pages.*

PM₁₀:

a criteria air pollutant that is particulate matter in ambient air exceeding 10 microns in diameter

Prevention of Significant Deterioration (PSD):

a program established by the Clean Air Act that limits the amount of additional air pollution that is allowed in Class I and Class II areas

primary standard:

a pollution standard based on human health effects. Primary standards are set for criteria air pollutants. *See also secondary standard.*

R-MAP:

Resource Management Assessment Program

reactive organic compounds:

(in the context of photochemically produced air pollution;) organic compounds that produce ozone in the presence of nitrogen oxides and sunlight. *See also* Volatile Organic Compounds.

reformulated gasoline:

specially-refined gasoline with low levels of smog-forming volatile organic compounds and low levels of hazardous air pollutants

regional haze:

a cloud of aerosols extending up to hundreds of miles across a region and promoting noticeably hazy conditions

secondary standard:

an air pollution limit based on environmental effects, e.g. damage to property, plants, visibility, etc. Secondary standards are set for criteria air pollutants. *See also* primary standard.

smog:

a mixture of air pollutants, principally ground-level ozone, produced by chemical reactions involving smog-forming chemicals. *See also* haze.

Southern Oxidant Study (SOS):

a study to assess the sources and transport of air pollutants contributing to ozone formation

source:

any place or object from which air pollutants are released. Sources that are fixed in space are stationary sources; sources that move are mobile sources. *See also* major source.

State Implementation Plan (SIP):

a collection of regulations used by the state to carry out its responsibilities under the Clean Air Act

stationary source:

a fixed source of regulated air pollutants (e.g. industrial facility). *See also* source; mobile sources.

sulfur dioxide (SO₂):

a criteria air pollutant that is a gas produced by burning coal and some industrial processes. *See also* acid deposition, sulfur dioxide park topics.

SUM60:

the daily sum of all valid hourly ozone concentrations equalling or exceeding 60 PPB for the day. Statistic is computed for all days with valid hourly ozone concentrations equalling or exceeding 60 PPB during the year or growing season. Units are PPB-HR.

temperature inversion:

weather condition in which warm air sits atop cooler air, promoting stagnation and increased concentrations of air pollutants.

toxic air pollutants:

see hazardous air pollutants.

transmissometer:

a device for assessing visibility conditions by measuring the amount of light received from a distant light source. *See* transmissometer exhibit.

total suspended particulates (TSP):

total particulate matter in a sample of ambient air

visual air quality:

air quality evaluated in terms of pollutant particles and gases that affect how well one can see through the atmosphere.

visual range:

an expression of visibility; the distance at which a large black object just disappears against the horizon.

Volatile Organic Compounds (VOC):

organic compounds that vaporize readily and contribute to the development of ozone. Many VOCs are also hazardous air pollutants. *See also reactive organic compounds.*



Latest Definitions of VOC and ROG - As Of April 14, 1998

1. U.S. EPA Definition of VOC (Volatile Organic Compounds):

The U.S. Environmental Protection Agency (U.S. EPA) defines and uses the term Volatile Organic Compounds (VOC). The term VOC is defined in the Federal Register. The original definition of VOC made reference to the vapor pressure of the compounds (greater than 0.1 millimeter of mercury) as a determinant of volatility. However, the current definition relies solely on a list of exempted compounds having "negligible photochemical reactivity".

U.S. EPA periodically exempts additional compounds. Proposed exemptions are pending. A summary follows.

RECENT FINAL RULEMAKINGS:

- (1) Acetone was exempted by final rule published June 16, 1995 (60 FR 31633).
- (2) Perchloroethylene was exempted by final rule published February 7, 1996 (61 FR 4588).
- (3) In response to petitions, the U.S. EPA exempted HFC 43-10mee, HCFC 225ca, and HCFC 225cb. The final rule was published October 8, 1996 (61 FR 52848), and became effective November 7, 1996.
- (4) The Alliance for Responsible Atmospheric Policy, Arlington, Virginia, petitioned to exempt 22 compounds, primarily HFCs and HCFCs, but later withdrew five of these. U.S. EPA exempted 16 of the 17 requested compounds (excluding HCFC-150a). The final rule was published August 25, 1997 (62 FR 44900), effective September 24, 1997.
- (5) U.S. EPA exempted Methyl acetate, in response to petition from Eastman Chemical, April 9, 1998 (63 FR 17331).

PENDING RULEMAKINGS AND PETITIONS (as of April 14, 1998):

- (6) According to Bill Johnson at U.S. EPA, OAQPS, the U.S. EPA is rethinking aspects of its reactivity policy, such as a molar vs. gram basis for reactivity. A national workshop is scheduled for May 12, 13, 14 in North Carolina.
- (7) U.S. EPA received petitions, which are pending review, requesting to exempt the following additional compounds:
 - Chlorobromomethane - from ICF Kaiser (SAI Division), San Rafael, California (11/95);
 - 1-Bromopropane - from EnviroTech International, Alameda, California (5/96);
 - Methyl bromide - from Chemical Manufacturers Association, Washington, D.C. (7/96);
 - N-Alkanes (C₁₂ - C₁₈) - from The Aluminum Association, Washington, D.C. (11/96);
 - Technical white oils - from The Printing Industries of America and Pennzoil Products Company (12/96);
 - t-Butyl acetate - from ARCO Chemical Company (1/97);
 - Benzotrifluoride - from Occidental Chemical Company, Niagara Falls, NY (3/97);
 - Carbonyl sulfide - from E.I. du Pont de Nemours and Company (8/97).
 - trans-1,2-Dichloroethylene - from 3M Corporation, St. Paul, MN (10/97).
 - Dimethyl succinate and Dimethyl glutarate - from the Dibasic Esters Group, affiliated with the Synthetic Organic Chemical Manufacturers Association, Inc. (10/97).
 - Carbon disulfide - Texas Mid-Continent Oil and Gas Association (12/97)
 - Acetonitrile - BP Chemicals and GNI Chemicals Corporation (12/98)
 - Toluene diisocyanate - Chemical Manufacturers Association (1/98)
 - HFC-227ea - Great Lakes Chemical Corporation (2/98)(U.S. EPA also previously received inquiries about methanol and isopropanol.)

The complete federal definition and the list of exempted compounds to date are shown on the following page.

U.S. EPA Definition of VOC (as of April 14, 1998): (based on final rules to date)

40 CFR Part 51 Section 51.100 Definitions.

- (s) **Volatile organic compounds (VOC)** means any compound of carbon, excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate, which participates in atmospheric photochemical reactions.
- (1) This includes any such organic compound other than the following, which have been determined to have negligible photochemical reactivity:
- | | |
|--|-----------------|
| methane; | [74-82-8] |
| ethane; | [74-84-0] |
| methylene chloride (dichloromethane); | [75-09-2] |
| 1,1,1-trichloroethane (methyl chloroform); | [71-55-6] |
| 1,1,2-trichloro-1,2,2-trifluoroethane (CFC-113); | [76-13-1] |
| trichlorofluoromethane (CFC-11); | [75-69-4] |
| dichlorodifluoromethane (CFC-12); | [75-43-4] |
| chlorodifluoromethane (HCFC-22); | [75-45-6] |
| trifluoromethane (HFC-23); | [75-46-7] |
| 1,2-dichloro-1,1,2,2-tetrafluoroethane (CFC-114); | [76-14-2] |
| chloropentafluoroethane (CFC-115); | [76-15-3] |
| 1,1,1-trifluoro-2,2-dichloroethane (HCFC-123); | [306-83-2] |
| 1,1,1,2-tetrafluoroethane (HFC-134a); | [811-97-2] |
| 1,1-dichloro-1-fluoroethane (HCFC-141b); | [1717-00-6] |
| 1-chloro-1,1-difluoroethane (HCFC-142b); | [75-68-3] |
| 2-chloro-1,1,1,2-tetrafluoroethane (HCFC-124); | [2837-89-0] |
| pentafluoroethane (HFC-125); | [354-33-6] |
| 1,1,2,2-tetrafluoroethane (HFC-134); | [359-35-3] |
| 1,1,1-trifluoroethane (HFC-143a); | [420-46-2] |
| 1,1-difluoroethane (HFC-152a); | [75-37-6] |
| parachlorobenzotrifluoride (PCBTf); | [98-56-6] |
| cyclic, branched, or linear completely methylated siloxanes; | [various] |
| acetone; | [67-64-1] |
| perchloroethylene (tetrachloroethylene); | [127-18-4] |
| 3,3-dichloro-1,1,1,2,2-pentafluoropropane (HCFC-225ca); | [422-56-0] |
| 1,3-dichloro-1,1,2,2,3-pentafluoropropane (HCFC-225cb); | [507-55-1] |
| 1,1,1,2,3,4,4,5,5,5-decafluoropentane (HFC-43-10mee); | [138495-42-8] |
| difluoromethane (HFC-32); | [75-10-5] |
| ethylfluoride (HFC-161); | [353-36-6] |
| 1,1,1,3,3,3-hexafluoropropane (HFC-236fa); | [690-39-1] |
| 1,1,2,2,3-pentafluoropropane (HFC-245ca); | [679-86-7] |
| 1,1,2,3,3-pentafluoropropane (HFC-245ea); | [24270-66-4] |
| 1,1,1,2,3-pentafluoropropane (HFC-245eb); | [431-31-2] |
| 1,1,1,3,3-pentafluoropropane (HFC-245fa); | [460-73-1] |
| 1,1,1,2,3,3-hexafluoropropane (HFC-236ea); | [431-63-0] |
| 1,1,1,3,3-pentafluorobutane (HFC-365mfc); | [406-58-6] |
| chlorofluoromethane (HCFC-31); | [593-70-4] |
| 1-chloro-1-fluoroethane (HCFC-151a); | [1615-75-4] |
| 1,2-dichloro-1,1,2-trifluoroethane (HCFC-123a); | [354-23-4] |
| 1,1,1,2,2,3,3,4,4-nonafluoro-4-methoxy-butane (C ₄ F ₉ OCH ₃); | [163702-07-6] |
| 2-(difluoromethoxymethyl)-1,1,1,2,3,3,3-heptafluoropropane ((CF ₃) ₂ CFCF ₂ OCH ₃); | [163702-08-7] |
| 1-ethoxy-1,1,2,2,3,3,4,4,4-nonafluorobutane (C ₄ F ₉ OC ₂ H ₅); | [163702-05-4] |
| 2-(ethoxydifluoromethyl)-1,1,1,2,3,3,3-heptafluoropropane ((CF ₃) ₂ CFCF ₂ OC ₂ H ₅); | [163702-06-5] |
| methyl acetate | [79-20-9] |
| and perfluorocarbon compounds which fall into these classes: | [various] |
| (i) Cyclic, branched, or linear, completely fluorinated alkanes; | |
| (ii) Cyclic, branched, or linear, completely fluorinated ethers with no unsaturations; | |
| (iii) Cyclic, branched, or linear, completely fluorinated tertiary amines with no unsaturations; and | |
| (iv) Sulfur containing perfluorocarbons with no unsaturations and with sulfur bonds only to carbon and fluorine. | |

* NOTE: Chemical Abstract Service (CAS) identification numbers have been included in brackets [] for convenience.

2. California Air Resources Board's Definition of ROG (Reactive Organic Gases):

The California Air Resources Board's (ARB's) Emission Inventory Branch (EIB) uses the terms Total Organic Gases (TOG) and Reactive Organic Gases (ROG). California air pollution control districts report Total Organic Gases (TOG) to the Air Resources Board's emission inventory.

For each source category, the ARB derives a value for the Reactive Organic Gases (ROG) by multiplying the reported TOG by the Fraction of Reactive Organic Gases (FROG). Each source category is keyed to one of some 200 available chemical speciation profiles. For each category, the FROG value is calculated as the weight fraction of those species designated by the ARB as reactive in the speciation profile applicable to the category. The ARB's organic gas speciation profiles are reported in the document Identification of Volatile Organic Compound Species Profiles: ARB Speciation Manual, Second Edition, Volume 1 of 2, August 1991.

The relationships among these organic gas terms are summarized as follows:

$$\begin{array}{ccccc} \text{TOG} & - & \text{Exempt cmpds} & = & \text{ROG} \\ \text{(Total Organic Gas)} & & [\text{ARB list of methane,} & & \text{(Reactive Organic Gas)} \\ & & \text{CFCs, etc.}] & & \end{array}$$

$$\begin{array}{ccccc} \text{TOG} & \times & \text{FROG} & = & \text{ROG} \\ \text{(Total Organic Gas)} & & \text{(Fraction of Reactive} & & \text{(Reactive Organic Gas)} \\ & & \text{Organic Gas)} & & \end{array}$$

The Air Pollution Emission Inventory Program manual, ARB, March 1982, listed the compounds which the ARB initially treated as exempted from ROG. The list differed somewhat from the U.S. EPA's list of exempted VOCs even at the time, in that ARB's definition of ROG did not exempt Ethane. As discussed in the prior section, U.S. EPA later exempted additional compounds from the federal definition of VOC as well.

Subsequently, the Air Resources Board was petitioned regarding exemptions from the ARB's regulations. The ARB staff formed a Reactive Organic Gas Technical Committee (ROGTC), made up of staff from the ARB's affected divisions and district representatives, to systematically evaluate the proposed exemption of these compounds. At a public hearing in September 1995, the Air Resources Board took action to revise the definition of Volatile Organic Compounds in the consumer products regulations, based on the recommendations of the ROGTC. Methyl siloxanes were added to the list of exempted compounds, and parachlorobenzotrifluoride, acetone, and ethane were added to the list of exempted compounds with the qualifier that they are "low-reactive organic compounds which have been exempted by the U.S. EPA". Based on the ROGTC's analysis, the staff similarly modified the overall inventory definition of ROG to extend the Board's action on the consumer products regulations to all inventory applications.

The Air Resources Board exempted Perchloroethylene from the definition of VOC in the Consumer Products regulations in November 1996. Perchloroethylene is under evaluation for other inventory categories.

The complete definitions and the list of exempted compounds to date are shown on the following page.

ARB's Definitions of TOG and ROG (as of April 14, 1998):

Total Organic Gases (TOG) means compounds of carbon, excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate.

Reactive Organic Gases (ROG) means any compound of carbon, excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate, and excluding the following:

- (1)

| | |
|---|---------------|
| methane; | [74-82-8]* |
| methylene chloride (dichloromethane); | [75-09-2] |
| 1,1,1-trichloroethane (methyl chloroform); | [71-55-6] |
| trichlorofluoromethane (CFC-11); | [75-69-4] |
| dichlorodifluoromethane (CFC-12); | [75-43-4] |
| 1,1,2-trichloro-1,2,2-trifluoroethane (CFC-113); | [76-13-1] |
| 1,2-dichloro-1,1,2,2-tetrafluoroethane (CFC-114); | [76-14-2] |
| chloropentafluoroethane (CFC-115); | [76-15-3] |
| chlorodifluoromethane (HCFC-22); | [75-45-6] |
| 1,1,1-trifluoro-2,2-dichloroethane (HCFC-123); | [306-83-2] |
| 2-chloro-1,1,1,2-tetrafluoroethane (HCFC-124); | [2837-89-0] |
| 1,1-dichloro-1-fluoroethane (HCFC-141b); | [1717-00-6] |
| 1-chloro-1,1-difluoroethane (HCFC-142b); | [75-68-3] |
| trifluoromethane (HFC-23); | [75-46-7] |
| pentafluoroethane (HFC-125); | [354-33-6] |
| 1,1,2,2-tetrafluoroethane (HFC-134); | [359-35-3] |
| 1,1,1,2-tetrafluoroethane (HFC-134a); | [811-97-2] |
| 1,1,1-trifluoroethane (HFC-143a); | [420-46-2] |
| 1,1-difluoroethane (HFC-152a); | [75-37-6] |
| cyclic, branched, or linear completely methylated siloxanes; | [various] |
| the following classes of perfluorocarbons: | [various] |
| (A) cyclic, branched, or linear, completely fluorinated alkanes; | |
| (B) cyclic, branched, or linear, completely fluorinated ethers with no unsaturations; | |
| (C) cyclic, branched, or linear, completely fluorinated tertiary amines with no unsaturations; and | |
| (D) sulfur-containing perfluorocarbons with no unsaturations and with the sulfur bonds only to carbon and fluorine; and | |
- (2) the following low-reactive organic compounds which have been exempted by the U.S. EPA:

| | |
|--|--------------|
| acetone; | [67-64-1] |
| | |
| ethane; | [74-84-0] |
| [perchloroethylene]**; and | [127-18-4] |
| parachlorobenzotrifluoride (1-chloro-4-trifluoromethyl benzene). | [98-56-6] |

* NOTE: Chemical Abstract Service (CAS) identification numbers have been included in brackets [] for convenience.

** The Air Resources Board exempted Perchloroethylene from the definition of VOC in the Consumer Products regulations in November 1996. Perchloroethylene is under evaluation for other inventory categories.

Relationships Among Organic Gas Terms
Used in the Emission Inventory

MOTOR VEHICLES:

$$1. \text{ NMHC } + \text{ methane } = \text{ HC } \quad \text{[or THC total hydrocarbons]}$$

(non-methane hydrocarbons) (hydrocarbons)

- NMHC and HC (THC) contain only hydrocarbons (not oxygenated compounds like aldehydes) due to GC-FID measurement technique
- NMHC and HC must be adjusted for the oxygenated compounds to get NMOG

$$2. \text{ NMHC } \xrightarrow{\text{adjust to add oxygenated cmpds}} \text{ NMOG }$$

(non-methane hydrocarbons) (non-methane organic gas)

$$3. \text{ NMOG } + \text{ methane } = \sim \text{ TOG }$$

(non-methane organic gas) approximately Total Organic Gas

OVERALL INVENTORY:

$$4. \text{ TOG } - \text{ Exempt cmpds } = \text{ ROG }$$

(Total Organic Gas) [ARB list of methane, ethane, CFCs, etc.] (Reactive Organic Gas)

$$5. \text{ TOG } \times \text{ FROG } = \text{ ROG }$$

(Fraction of Reactive Organic Gas) (Reactive Organic Gas)

$$6. \text{ TOG } \times \text{ FR_VOC } = \text{ VOC }$$

(Fraction of Volatile Organic Cmpds) (Volatile Organic Cmpds)

-- "VOC" is U.S. EPA term -- uses a separate federal list of exempted cmpds

Conversion Factors for Motor Vehicles:

| | <u>THC / TOG</u> | <u>FROG</u> | <u>FR_VOC</u> |
|---|------------------|-------------|---------------|
| Non-catalyst gasoline vehicle- exhaust: (Profile 527) | .9434 | .9147 | .9147 |
| Catalyst gasoline vehicle - exhaust: (Profile 801) | .9441 | .8277 | .8277 |
| Gasoline vehicle - evaporative: (Profile 709) | 1.0000 | 1.0000 | 1.0000 |
| Diesel vehicle - exhaust: (Profile 561) | .8319 | .9716 | .9716 |

From: Methodology for Estimating Emissions from On-Road Motor Vehicles; Volume VI: Compilation of Equations Used in the EMFAC, WEIGHT, and BURDEN Models; ARB, November 1996.

1000 APPENDICES

**Ambient
Air
Monitoring**

APPENDIX B

EPA REFERENCE AND EQUIVALENT METHODS

July 2000

U.S. EPA REFERENCE & EQUIVALENT METHODS FOR AMBIENT AIR

September 1, 1999

| Method | Designation Number | Method Code | Method | Designation Number | Method Code |
|--------------------------------------|--------------------|-------------|--|--------------------|-------------|
| SO₂ Manual Methods | | | NO_x Analyzers | | |
| Reference method (pararosaniline) | ... | 097 | Advanced Pollution Instr. 200 | RFNA-0691-082 | 082 |
| Technicon I (pararosaniline) | EQS-0775-001 | 097 | Advanced Pollution Instr. 200A | RFNA-1194-099 | 099 |
| Technicon II (pararosaniline) | EQS-0775-002 | 097 | Beckman 952A | RFNA-0179-034 | 034 |
| SO₂ Analyzers | | | Bendix 8101-B | RFNA-0479-038 | 038 |
| Advanced Pollution Instr. 100 | EQSA-0990-077 | 077 | Bendix 8101-C | RFNA-0777-022 | 022 |
| Advanced Pollution Instr. 100A | EQSA-0495-100 | 100 | Columbia Scientific Indust. 1600, 5600 | RFNA-0977-025 | |
| Asarco 500 | EQSA-0877-024 | 024 | 025 | | |
| Beckman 953 | EQSA-0678-029 | 029 | Dasibi 2108 | RFNA-1192-089 | 089 |
| Bendix 8303 | EQSA-1078-030 | 030 | DKK Corp GLN-114E | RFNA-0798-121 | 121 |
| Columbia Scientific Industries 5700 | EQSA-0494-095 | 095 | Environnement S.A. AC31M | RFNA-0795-104 | 104 |
| Dasibi 4108 | EQSA-1086-061 | 061 | Horiba APNA-360 | RFNA-0196-111 | 111 |
| DKK Corp. Model GFS-32 | EQSA-0701-115 | | Lear Siegler or Monitor Labs ML9841B. | | |
| 115 | | | ML9841A, Monitor Labs ML9841B. | | |
| Environnement S.A. AF21M | EQSA-0292-084 | 084 | Wedding 1030 | RFNA-1292-090 | 090 |
| Horiba Model APSA-360/APSA-360ACE | EQSA-0197-114 | 114 | Meloy NA530R | RFNA-1078-031 | 031 |
| Lear Siegler AM2020 | EQSA-1280-049 | 049 | Monitor Labs 8440E | RFNA-0677-021 | 021 |
| Lear Siegler SM1000 | EQSA-1275-005 | 005 | Monitor Labs or Lear Siegler 8840 | RFNA-0280-042 | 042 |
| Lear Siegler or Monitor Labs ML9850. | | | Monitor Labs or Lear Siegler 8841 | RFNA-0991-083 | 083 |
| Monitor Labs ML9850B, Wedding 1040 | EQSA-0193-092 | 092 | Opsis AR 500, System 300 (open path) | EQNA-0495-102 | 102 |
| Meloy SA185-2A | EQSA-1275-006 | 006 | Philips PW9762/02 | RFNA-0879-040 | 040 |
| Meloy SA285E | EQSA-1078-032 | 032 | Thermo Electron or Thermo | | |
| Meloy SA700 | EQSA-0580-046 | 046 | Environmental Instruments 14B/E | RFNA-0179-035 | 035 |
| Monitor Labs 8450 | EQSA-0876-013 | 513 | Thermo Electron or Thermo | | |
| Monitor Labs or Lear Siegler 8850 | EQSA-0779-039 | 039 | Environmental Instruments 14D/E | RFNA-0279-037 | 037 |
| Monitor Labs or Lear Siegler 8850S | EQSA-0390-075 | 075 | Thermo Environmental Instr. 42, 42C | RFNA-1289-074 | 074 |
| Opsis AR 500, System 300 (open path) | EQSA-0495-101 | 101 | Pb Manual Methods | | |
| Philips PW9700 | EQSA-0876-011 | 511 | Reference method (hi-vol/AA spect.) | | 803 |
| Philips PW9755 | EQSA-0676-010 | 010 | Hi-vol/AA spect. (alt. extr.) | EQL-0380-043 | 043 |
| Thermo Electron 43 | EQSA-0276-009 | 009 | Hi-vol/Energy-disp XRF (TX ACB) | EQL-0783-058 | 058 |
| Thermo Electron 43A or Thermo | | | Hi-vol/Energy-disp XRF (NEA) | EQL-0589-072 | 072 |
| Environmental Instruments 43B, 43C | EQSA-0486-060 | 060 | Hi-vol/Flameless AA (EMSL/EPA) | EQL-0380-044 | 044 |
| O₃ Analyzers | | | Hi-vol/Flameless AA (Houston) | EQL-0895-107 | 107 |
| Advanced Pollution Instr. 400/400A | EQOA-0992-087 | 087 | Hi-vol/Flameless AA (Omaha) | EQL-0785-059 | 059 |
| Beckman 950A | RFOA-0577-020 | 020 | Hi-vol/ICAP spect. (Doe Run Co.) | EQL-0196-113 | 113 |
| Bendix 8002 | RFOA-0176-007 | 007 | Hi-vol/ICAP spect. (EMSL/EPA) | EQL-0380-045 | 045 |
| Columbia Scientific Industries 2000 | RFOA-0279-036 | 036 | Hi-vol/ICAP spect. (Illinois) | EQL-1193-094 | 094 |
| Dasibi 1003-AH, PC-RS | EQOA-0577-019 | 019 | Hi-vol/ICAP spect. (Kansas) | EQL-0592-085 | 085 |
| Dasibi 1008-AH | EQOA-0383-056 | 056 | Hi-vol/ICAP spect. (Montana) | EQL-0483-057 | 057 |
| Enviroconics 300 | EQOA-0990-078 | 078 | Hi-vol/ICAP spect. (NE&T) | EQL-1188-069 | 069 |
| Environnement S.A. O ₄ 1M | EQOA-0895-105 | 105 | Hi-vol/ICAP spect. (New Hampshire) | EQL-1290-080 | 080 |
| Horiba APOA-360 | EQOA-0196-112 | 112 | Hi-vol/ICAP spect. (Pennsylvania) | EQL-0592-086 | 086 |
| Lear Siegler or Monitor Labs ML9810. | | | Hi-vol/ICAP spect. (Pima Co., AZ) | EQL-0995-109 | 109 |
| Monitor Labs ML9810B, Wedding 1010 | EQOA-0193-091 | 091 | Hi-vol/ICAP spect. (Pima Co., AZ) | EQL-0995-110 | 110 |
| McMillan 1100-1 | RFOA-1076-014 | 514 | Hi-vol/ICAP spect. (Rhode Island) | EQL-0888-068 | 068 |
| McMillan 1100-2 | RFOA-1076-015 | 515 | Hi-vol/ICAP spect. (Silver Val. Labs) | EQL-1288-070 | 070 |
| McMillan 1100-3 | RFOA-1076-016 | 016 | Hi-vol/ICAP spect. (West Virginia) | EQL-0694-096 | 096 |
| Meloy OA325-2R | RFOA-1075-003 | 003 | Hi-vol/WL-disp. XRF (CA A&IHL) | EQL-0581-052 | 052 |
| Meloy OA350-2R | RFOA-1075-004 | 004 | PM₁₀ Samplers | | |
| Monitor Labs 8410E | RFOA-1176-017 | 017 | Andersen Instruments, RAAS10-100 | RFPS-0699-130 | 130 |
| Monitor Labs or Lear Siegler 8810 | EQOA-0881-053 | 053 | Andersen Instruments, RAAS10-200 | RFPS-0699-131 | 131 |
| Opsis AR 500, System 300 (open path) | EQOA-0495-103 | 103 | Andersen Instruments, RAAS10-300 | RFPS-0699-132 | 132 |
| PCI Ozone Corp. LC-12 | EQOA-0382-055 | 055 | BGI Model PQ100 | RFPS-1298-124 | 124 |
| Philips PW9771 | EQOA-0777-023 | 023 | BGI Model PQ200 | RFPS-1298-125 | 125 |
| Thermo Electron or Thermo | | | Oregon DEQ Medium volume sampler | RFPS-0389-071 | 071 |
| Environmental Instruments 49, 49C | EQOA-0880-047 | 047 | Ruppel & Patashnick Partisol 2000 | RFPS-0694-098 | 098 |
| CO Analyzers | | | R & P Partisol-FRM Model 2000 | RFPS-1298-126 | 126 |
| Advanced Pollution Instr. 300 | RFCA-1093-093 | 093 | R & P Partisol-Plus Model 2025 Seq. | RFPS-1298-127 | 127 |
| Beckman 866 | RFCA-0876-012 | 012 | Sierra-Andersen/GMW 1200 | RFPS-1287-063 | 063 |
| Bendix 8501-5CA | RFCA-0276-008 | 008 | Sierra-Andersen/GMW 321-B | RFPS-1287-064 | 064 |
| Dasibi 3003 | RFCA-0381-051 | 051 | Sierra-Andersen/GMW 321-C | RFPS-1287-065 | 065 |
| Dasibi 3008 | RFCA-0488-067 | 067 | Sierra-Andersen/GMW 241 Dichot. | RFPS-0789-073 | 073 |
| Environnement s.a. CO11M | RFCA-0995-108 | 108 | W&A/Thermo Electron Mod 600 HVI. | RFPS-1087-062 | 062 |
| Horiba AQM-10, -11, -12 | RFCA-1278-033 | 033 | PM₁₀ Analyzers | | |
| Horiba 300E/300SE | RFCA-1180-048 | 048 | Andersen Instruments Beta FH621-N | EQPM-0990-076 | 076 |
| Horiba APMA-360 | RFCA-0895-106 | 106 | Met One BAM1020, GBAM1020, | | |
| Lear Siegler or Monitor Labs ML9830. | | | BAM1020-1, GBAM1020-1 | EQPM-0798-122 | 122 |
| Monitor Labs ML9830B, Wedding 1020 | RFCA-0992-088 | 088 | R & P TEOM 1400, 1400a | EQPM-1090-079 | 079 |
| MASS - CO 1 (Massachusetts) | RFCA-1280-050 | 050 | W&A/Thermo Electron 650 Beta Gauge | EQPM-0391-081 | 081 |
| Monitor Labs 8310 | RFCA-0979-041 | 041 | PM_{2.5} Samplers | | |
| Monitor Labs or Lear Siegler 8830 | RFCA-0388-066 | 066 | Andersen Model RAAS2.5-200 Audit | RFPS-0299-128 | 128 |
| MSA 202S | RFCA-0177-018 | 018 | BGI PQ200/200A | RFPS-0498-116 | 116 |
| Thermo Electron or Thermo | | | Graseby Andersen RAAS2.5-100 | RFPS-0598-119 | 119 |
| Environmental Instruments 48, 48C | RFCA-0981-054 | 054 | Graseby Andersen RAAS2.5-300 | RFPS-0598-120 | 120 |
| NO_x Manual Methods | | | R & P Partisol-FRM 2000 | RFPS-0498-117 | 117 |
| Sodium arsenite (orifice) | EQN-1277-026 | 084 | R & P Partisol-Plus 2025 | RFPS-0498-118 | 118 |
| Sodium arsenite/Technicon II | EQN-1277-027 | 084 | Thermo Envr Model 605 CAPS | RFPS-1098-123 | 123 |
| TGS-ANSA (orifice) | EQN-1277-028 | 098 | R & P Partisol 2000 Audit | RFPS-0499-129 | 129 |
| TSP Manual Method | | | Reference method (high-volume) | | 802 |



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
NATIONAL EXPOSURE RESEARCH LABORATORY
HUMAN EXPOSURE & ATMOSPHERIC SCIENCES DIVISION (MD-46)
Research Triangle Park, NC 27711
919-541-2622

Office of
Research and Development

LIST OF DESIGNATED REFERENCE AND EQUIVALENT METHODS

Issue Date: September 1, 1999

(www.epa.gov/ttn/amtic/criteria.html)

These methods for measuring ambient concentrations of specified air pollutants have been designated as "reference methods" or "equivalent methods" in accordance with Title 40, Part 53 of the Code of Federal Regulations (40 CFR Part 53). Subject to any limitations (e.g., operating range) specified in the applicable designation, each method is acceptable for use in state or local air quality surveillance systems under 40 CFR Part 58 unless the applicable designation is subsequently canceled. Automated methods are acceptable for use at shelter temperatures between 20°C and 30°C and line voltages between 105 and 125 volts unless wider limits are specified in the method description.

Prospective users of the methods listed should note (1) that each method must be used in strict accordance with its associated operation or instruction manual and with applicable quality assurance procedures, and (2) that modification of a method by its vendor or user may cause the pertinent designation to be inapplicable to the method as modified. (See Section 2.8 of Appendix C, 40 CFR Part 58 for approval of modifications to any of these methods by users.)

Further information concerning particular designations may be found in the *Federal Register* notice cited for each method or by writing to the National Exposure Research Laboratory, Human Exposure and Atmospheric Sciences Division (MD-46), U.S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711. Technical information concerning the methods should be obtained by contacting the source listed for each method. Source addresses are listed at the end of each listing of methods, except for the addresses for lead method sources, which are given with the method. New analyzers or PM₁₀ samplers sold as reference or equivalent methods must carry a label or sticker identifying them as designated methods. For analyzers or PM₁₀ samplers sold prior to the designation of a method with the same or similar model number, the model number does not necessarily identify an analyzer or sampler as a designated method. Consult the manufacturer or seller to determine if a previously sold analyzer or sampler can be considered a designated method or if it can be upgraded to designation status. Analyzer users who experience operational or other difficulties with a designated analyzer or sampler and are unable to resolve the problem directly with the instrument manufacturer may contact EPA (preferably in writing) at the above address for assistance.

This list will be revised as necessary to reflect any new designations or any cancellation of a designation currently in effect. The most current revision of the list will be available for inspection at EPA's Regional Offices, and copies may be obtained by writing to the National Exposure Research Laboratory at the address specified above.

Most Recent Designations

BGI Inc. Model PQ200/PQ200A PM_{2.5} Ambient Fine Particle Sampler, April 1998
Rupprecht & Patashnick, Inc. Partisol®-FRM Model 2000 PM-2.5 Air Sampler, April 1998
Rupprecht & Patashnick, Inc. Partisol®-Plus Model 2025 PM-2.5 Sequential Air Sampler, April 1998
Graseby Andersen Model RAAS2.5-100 PM_{2.5} Ambient Air Sampler, June 1998
Graseby Andersen Model RAAS2.5-300 PM_{2.5} Sequential Ambient Air Sampler, June 1998
Horiba Instruments, Inc. Model APSA-360/APSA-360 CE/APSA-360ACE Ambient SO₂ Monitor, June 1998
Advanced Pollution Instrumentation, Inc. Model 400A Ozone Analyzer, June 1998
DKK Corporation Model GLN-114E Nitrogen Oxides Analyzer, August 1998
Met One Instruments, Inc. Models BAM1020/1021-1, GBAM1020/1020-1 PM₁₀ Beta Attenuation Monitors, August 1998
Thermo Environmental, Inc. Model 605 "CAPS" Sampler, October 1998
BGI Inc. Models PQ100 and PQ200 PM₁₀ Air Samplers, December 1998
Rupprecht & Patashnick, Inc. Partisol®-FRM Model 2000 PM-10 Air Sampler, December 1998
Rupprecht & Patashnick, Inc. Partisol®-Plus Model 2025 PM-10 Sequential Air Sampler, December 1998
Andersen Model RAAS2.5-200 PM2.5 Audit Air Sampler, March 1999
Rupprecht & Patashnick, Inc. Partisol® Model 2000 PM-2.5 Audit Sampler, April 1999
Andersen Models RAAS10-100, RAAS10-200, and RAAS10-300 Samplers, June 1999

PARTICULATE MATTER - TSP**Reference Method for TSP***Manual Reference Method: 40 CFR Part 50, Appendix B*

Reference Method for the Determination of Suspended Particulate Matter in the Atmosphere (High-Volume Method)

[Federal Register: Vol 47, page 54912, 12/06/82 and Vol 48, page 17355, 04/22/83]

PARTICULATE MATTER - PM₁₀**Andersen Model RAAS10-100 PM10 Single Channel PM₁₀ Sampler***Manual Reference Method: RFPS-0699-130*

"Andersen Instruments, Incorporated Model RAAS10-100 Single Channel Reference Method PM₁₀ Sampler," with RAAS-10 PM₁₀ inlet, configured as a PM₁₀ reference method, and operated for 24-hour continuous sample periods at a flow rate of 16.67 liters/minute, and in accordance with the Model RAAS105-100 Operator's Manual and with the requirements and sample collection filters specified in 40 CFR Part 50, Appendix J or Appendix M.

[Federal Register: Vol 64, page 33481, 06/23/99]

Andersen Model RAAS10-200 PM10 Single Channel PM₁₀ Audit Sampler*Manual Reference Method: RFPS-0699-131*

"Andersen Instruments, Incorporated Model RAAS10-200 Single Channel Reference Method PM₁₀ Audit Sampler," with RAAS-10 PM₁₀ inlet, configured as a PM₁₀ reference method, and operated for 24-hour continuous sample periods at a flow rate of 16.67 liters/minute, and in accordance with the Model RAAS105-200 Operator's Manual and with the requirements and sample collection filters specified in 40 CFR Part 50, Appendix J or Appendix M.

[Federal Register: Vol 64, page 33481, 06/23/99]

Andersen Model RAAS10-300 PM10 Multi Channel PM₁₀ Sampler*Manual Reference Method: RFPS-0699-132*

"Andersen Instruments, Incorporated Model RAAS10-300 Multi Channel Sequential Reference Method PM₁₀ Sampler," with RAAS-10 PM₁₀ inlet, configured as a PM₁₀ reference method, and operated for 24-hour continuous sample periods at a flow rate of 16.67 liters/minute, and in accordance with the Model RAAS105-300 Operator's Manual and with the requirements and sample collection filters specified in 40 CFR Part 50, Appendix J or Appendix M.

[Federal Register: Vol 64, page 33481, 06/23/99]

BGI Incorporated Model PQ100 Air Sampler*Manual Reference Method: RFPS-1298-124*

"BGI Incorporated Model PQ100 Air Sampler" with BGI16.7 Inlet Kit, configured as a PM₁₀ reference method, for 24-hour continuous sample periods at a flow rate of 16.7 liters/minute, and operated in accordance with the Model PQ100 Instruction Manual and with the requirements specified in 40 CFR Part 50, Appendix J or Appendix M, using either the original or the newer PQ200-type filter cassettes.

[Federal Register: Vol 63, page 69625, 12/17/98]

BGI Incorporated Model PQ200 Air Sampler*Manual Reference Method: RFPS-1298-125*

"BGI Incorporated Model PQ200 Air Sampler" with "flat plate" PM₁₀ inlet, configured as a PM₁₀ reference method, and operated for 24-hour continuous sample periods in accordance with the Model PQ200 Instruction Manual and with the requirements specified in 40 CFR Part 50, Appendix J or Appendix M.

[Federal Register: Vol 63, page 69625, 12/17/98]

Graseby Andersen/GMW Model 1200 High-Volume Air Sampler*Manual Reference Method: RFPS-1287-063*

"Sierra-Andersen or General Metal Works Model 1200 PM₁₀ High-Volume Air Sampler System," consisting of a Sierra-Andersen or General Metal Works Model 1200 PM₁₀ Size-Selective Inlet and any of the high-volume air samplers identified as SAUV-10H, SAUV-11H, GMW-IP-10, GMW-IP-10-70, GMW-IP-10-801, or GMW-IP-10-8000, which include the following components: Anodized aluminum high-volume shelter with either acrylonitrile butadiene styrene plastic filter holder and motor/blower housing or stainless steel filter holder and phenolic plastic motor/blower housing; 0.6 hp motor/blower; pressure transducer flow recorder; either an electronic mass flow controller or a volumetric flow controller; either a digital timer/programmer, seven-day mechanical timer, six-day timer/programmer, or solid-state timer/programmer; elapsed time indicator; and filter cartridge.

[Federal Register: Vol 52, page 45684, 12/01/87 and Vol 53, page 1062, 01/15/88]

Graseby Andersen/GMW Model 321-B High-Volume Air Sampler*Manual Reference Method: RFPS-1287-064*

"Sierra-Andersen or General Metal Works Model 321-B PM₁₀ High-Volume Air Sampler System," consisting of a Sierra-Andersen or General Metal Works Model 321-B PM₁₀ Size-Selective Inlet and any of the high-volume air samplers identified as SAUV-10H, SAUV-11H, GMW-IP-10, GMW-IP-10-70, GMW-IP-10-801, or GMW-IP-10-8000, which include the following components: Anodized aluminum high-volume shelter with either acrylonitrile butadiene styrene plastic filter holder and motor/blower housing or stainless steel filter holder and phenolic plastic motor/blower housing; 0.6 hp motor/blower; pressure transducer flow recorder; either an electronic mass flow controller or a volumetric flow controller; either a digital timer/programmer, seven-day mechanical timer, six-day timer/programmer, or solid-state timer/programmer; elapsed time indicator; and filter cartridge.

[Federal Register: Vol 52, page 45684, 12/01/87 and Vol 53, page 1062, 01/15/88]

Graseby Andersen/GMW Model 321-C High-Volume Air SamplerManual Reference Method: **RFPS-1287-065**

"Sierra-Andersen or General Metal Works Model 321-C PM₁₀ High-Volume Air Sampler System," consisting of a Sierra-Andersen or General Metal Works Model 321-C PM₁₀ or Size-Selective Inlet and any of the high-volume air samplers identified as SAUV-10H, SAUV-11H, GMW-IP-10, GMW-IP-10-70, GMW-IP-10-801, or GMW-IP-10-8000, which include the following components: Anodized aluminum high-volume shelter with either acrylonitrile butadiene styrene plastic filter holder and motor/blower housing or stainless steel filter holder and phenolic plastic motor/blower housing; 0.6 hp motor/blower; pressure transducer flow recorder; either an electronic mass flow controller or a volumetric flow controller; either a digital timer/programmer, seven-day mechanical timer, six-day timer/programmer, or solid-state timer/programmer; elapsed time indicator; and filter cartridge.

[Federal Register: Vol 52, page 45684, 12/01/87 and Vol 53, page 1062, 01/15/88]

Graseby Andersen/GMW Models SA241 and SA241M Dichotomous SamplerManual Reference Method: **RFPS-0789-073**

"Sierra-Andersen Models SA241 and SA241M or General Metal Works Models G241 and G241M PM₁₀ Dichotomous Samplers," consisting of the following components: Sampling Module with SA246b or G246b 10 µm inlet, 2.5 µm virtual impactor assembly, 37 mm coarse and fine particulate filter holders, and tripod mount; Control Module with diaphragm vacuum pump, pneumatic constant flow controller, total and coarse flow rotameters and vacuum gauges, pressure switch (optional), 24-hour flow/event recorder, digital timer/programmer or 7-day skip timer, and elapsed time indicator.

[Federal Register: Vol 54, page 31247, 07/27/89]

Graseby Andersen/GMW Model FH621-N Beta MonitorAutomated Equivalent Method: **EQPM-0990-076**

"Andersen Instruments Model FH621-N PM₁₀ Beta Attenuation Monitor," consisting of the following components: FH101 Vacuum Pump Assembly; FH102 Accessory Kit; FH107 Roof Flange Kit; FH125 Zero and Span PM₁₀ Mass Foil Calibration Kit; FH621 Beta Attenuation 19-inch Control Module; SA246b PM₁₀ Inlet (16.7 liter/min); operated for 24-hour average measurements, with an observing time of 60 minutes, the calibration factor set to 2400, a glass fiber filter tape, an automatic filter advance after each 24-hour sample period, and with or without either of the following options: FH0P1 Indoor Cabinet; FH0P2 Outdoor Shelter Assembly.

[Federal Register: Vol 55, page 38387, 09/18/90]

Met One Models BAM 1020, GBAM 1020, BAM 1020-1, and GBAM 1020-1 Automated Equivalent Method: **EQPM-0798-**

"Met One Instruments Models BAM 1020, GBAM 1020, BAM 1020-1, and GBAM 1020-1 PM₁₀ Beta Attenuation Monitor," including the BX-802 sampling inlet, operated for 24-hour average measurements, with a filter change frequency of one hour, with glass fiber filter tape, and with or without any of the following options: BX-823, tube extension; BX-825, heater kit; BX-826, 230 Vac heater kit; BX-828, roof tripod; BX-902, exterior enclosure; BX-903, exterior enclosure with temperature control; BX-961, mass flow controller; BX-967, internal calibration device

[Federal Register: Vol 63, page 41253, 08/03/98]

Oregon DEQ Medium Volume PM₁₀ SamplerManual Reference Method: **RFPS-0389-071**

"Oregon DEQ Medium Volume PM₁₀ Sampler." NOTE: This method is not now commercially available.

[Federal Register: Vol 54, page 12273, 03/24/89]

Rupprecht & Patashnick TEOM Series 1400/1400a PM₁₀ MonitorsAutomated Equivalent Method: **EQPM-1090-079**

"Rupprecht & Patashnick TEOM Series 1400 and Series 1400a PM-10 Monitors," consisting of the following components: TEOM Sensor Unit; TEOM Control Unit; Flow Splitter (3 liter/min sample flow); Teflon-Coated Glass Fiber Filter Cartridges; Rupprecht & Patashnick PM-10 Inlet (part number 57-00596) or Sierra-Andersen Model 246b PM-10 Inlet (16.7 liter/min); operated for 24-hour average measurements, with the total mass averaging time set at 300 seconds, the mass rate/mass concentration averaging time set at 300 seconds, the gate time set at 2 seconds, and with or without any of the following options: Tripod; Outdoor Enclosure; Automatic Cartridge Collection Unit (Series 1400a only); Flow Splitter Adapter (for 1 or 2 liter/min sample flow).

[Federal Register: Vol 55, page 43406, 10/29/90]

Rupprecht & Patashnick Partisol Model 2000 Air SamplerManual Reference Method: **RFPS-0694-098**

"Rupprecht & Patashnick Partisol Model 2000 Air Sampler," consisting of a Hub Unit and 0, 1, 2, or 3 Satellite Units, with each sampling station used for PM₁₀ measurements equipped with a Rupprecht & Patashnick PM-10 inlet and operated for continuous 24-hour periods using the Basic, Manual, Time, Analog Input, or Serial Input programming modes, and with or without any of the following options: PM_{2.5}-style filter cassette holder; 57-002320 Stand for Hub or Satellite; 59-002542 Advanced EPROM; 10-001403 Large Pump (1/4 hp); 120 VAC. Hardware for Indoor Installation consists of: 51-002638-xxxx Temperature Sensor (Exterior Length); 55-001289 Roof Flange (1 1/4"); 57-000604 Support Tripod for Inlet; 57-002526-0001 Sample Tube Extension (1 m); 57-002526-0002 Sample Tube Extension (2 m). Hardware for Outdoor Installation in Extreme Cold Environments consists of: 10-002645 Insulating Jacket for Hub Unit.

[Federal Register: Vol 59, page 35338, 07/11/94]

Rupprecht and Patashnick Co. Partisol®-FRM Model 2000 PM₁₀ Air Sampler *Manual Reference Method: RFPS-1298-126*
"Rupprecht and Patashnick Company Partisol®-FRM Model 2000 PM₁₀ Air Sampler" with PM₁₀ inlet, configured as a PM₁₀ reference method, and operated for 24-hour continuous sample periods in accordance with the Model 2000 Instruction Manual and with the requirements specified in 40 CFR Part 50, Appendix J or Appendix M.
[Federal Register: Vol 63, page 69625, 12/17/98]

Rupprecht and Patashnick Partisol®-Plus Model 2025 PM₁₀ Seq. Air Sampler *Manual Reference Method: RFPS-1298-127*
"Rupprecht and Patashnick Company Partisol®-Plus Model 2025 PM₁₀ Sequential Air Sampler" with PM₁₀ inlet, configured as a PM₁₀ reference method, and operated for 24-hour continuous sample periods in accordance with the Model 2025 Instruction Manual and with the requirements specified in 40 CFR Part 50, Appendix J or Appendix M.
[Federal Register: Vol 63, page 69625, 12/17/98]

Wedding & Associates' or Thermo Environmental Instruments Inc. Model 600 PM₁₀ High-Volume Sampler *Manual Reference Method: RFPS-1087-062*
"Wedding & Associates' or Thermo Environmental Instruments, Inc. Model 600 PM₁₀ Critical Flow High-Volume Sampler," consisting of the following W&A/TEI components: PM₁₀ Inlet; Critical Flow Device; Anodized Aluminum Shelter; Blower Motor Assembly for 115, 220 or 240 VAC and 50/60 Hz; Mechanical Timer; Elapsed Time Indicator; and Filter Cartridge/Cassette, and with or without the following options: Digital Timer, 6 or 7 Day Timer, and 1 or 7 Day Pressure Recorder.
[Federal Register: Vol 52, page 37366, 10/06/87]

Wedding & Associates' or Thermo Environmental Instruments Inc. Model 650 PM₁₀ Beta Gauge *Automated Equivalent Method: EQPM-0391-081*
"Wedding & Associates' or Thermo Environmental Instruments, Inc. Model 650 PM₁₀ Beta Gauge Automated Particle Sampler," consisting of the following W&A/TEI components: Particle Sampling Module, PM₁₀ Inlet (18.9 liter/min), Inlet Tube and Support Ring, Vacuum Pump (115, 220 or 240 VAC and 50/60 Hz); and operated for 24-hour average measurements with glass fiber filter tape.
[Federal Register: Vol 56, page 9216, 03/05/91]

PARTICULATE MATTER - PM_{2.5}

Andersen Model RAAS2.5-200 PM_{2.5} Ambient Audit Air Sampler *Manual Reference Method: RFPS-0299-128*
"Andersen Instruments, Incorporated Model RAAS2.5-200 PM_{2.5} Audit Sampler," configured as a PM_{2.5} reference method and operated with software (firmware) version 4B, for 24-hour continuous sample periods at a flow rate of 16.67 liters/minute, and in accordance with the Model RAAS2.5-200 Operator's Manual and with the requirements and sample collection filters specified in 40 CFR Part 50, Appendix L.
[Federal Register: Vol 64, page 12167, 03/11/99]

BGI Inc. Models PQ200 and PQ200A PM_{2.5} Ambient Fine Particle Sampler *Manual Reference Method: RFPS-0498-116*
"BGI Incorporated Models PQ200 and PQ200APM_{2.5} Ambient Fine Particle Sampler," operated with firmware version 3.88 or 3.89R, for 24-hour continuous sample periods, in accordance with the Model PQ200/PQ200A Instruction Manual and with the requirements and sample collection filters specified in 40 CFR Part 50, Appendix L, and with or without the optional dual-filter cassette (P/N F-21/6) and associated lower impactor housing (P/N B2027), where the upper filter is used for PM_{2.5}. The Model PQ200A is described as a portable audit sampler and includes a set of three carrying cases.
[Federal Register: Vol 63, page 18911, 04/16/98]

Graseby Andersen Model RAAS2.5-100 PM_{2.5} Ambient Air Sampler *Manual Reference Method: RFPS-0598-119*
"Graseby Andersen Model RAAS2.5-100 PM_{2.5} Ambient Air Sampler," operated with software version 4B configured for "Single 2.5" operation, for 24-hour continuous sample periods at a flow rate of 16.67 liters/minute, and in accordance with the Model RAAS2.5-100 Operator's Manual and with the requirements and sample collection filters specified in 40 CFR Part 50, Appendix L.
[Federal Register: Vol 63, page 31991, 06/11/98]

Graseby Andersen Model RAAS2.5-300 PM_{2.5} Sequential Ambient Air Sampler *Manual Reference Method: RFPS-0598-120*
"Graseby Andersen Model RAAS2.5-300 PM_{2.5} Sequential Ambient Air Sampler," operated with software version 4B configured for "Multi 2.5" operation, for 24-hour continuous sample periods at a flow rate of 16.67 liters/minute, and in accordance with the Model RAAS2.5-300 Operator's Manual and with the requirements and sample collection filters specified in 40 CFR Part 50, Appendix L.
[Federal Register: Vol 63, page 31991, 06/11/98]

Rupprecht & Patashnick Partisol®-FRM Model 2000 Air SamplerManual Reference Method: **RFPS-0498-117**

"Rupprecht & Patashnick Company, Incorporated Partisol®-FRM Model 2000 PM-2.5 Air Sampler," operated with software vers. 1.102, 1.103, or 1.2, with either R&P-specified machined or molded filter cassettes, with or without the optional insulating jacket for cold weather operation, for 24-hour continuous sample periods, in accordance with the Model 2000 Instruction Manual and with the requirements and sample collection filters specified in 40 CFR Part 50, Appendix L.

[Federal Register: Vol 63, page 18911, 04/16/98]

Rupprecht & Patashnick Partisol® Model 2000 PM-2.5 Audit SamplerManual Reference Method: **RFPS-0499-129**

"Rupprecht & Patashnick Company, Inc. Partisol® Model 2000 PM-2.5 Audit Sampler," configured as a PM_{2.5} reference method and operated with software (firmware) version 1.2, for 24-hour continuous sample periods at a flow rate of 16.67 liters/minute, in accordance with the Partisol® Model 2000 Operating Manual and with the requirements and sample collection filters specified in 40 CFR Part 50, Appendix L.

[Federal Register: Vol 64, page 19153, 04/19/99]

Rupprecht & Patashnick Partisol®-Plus Model 2025 Sequential Air SamplerManual Reference Method: **RFPS-0498-118**

"Rupprecht & Patashnick Company, Incorporated Partisol®-Plus Model 2025 PM-2.5 Sequential Air Sampler," operated with any software version 1.003 through 1.302, with either R&P-specified machined or molded filter cassettes, for 24-hour continuous sample periods, in accordance with the Model 2025 Instruction Manual and with the requirements and sample collection filters specified in 40 CFR Part 50, Appendix L.

[Federal Register: Vol 63, page 18911, 04/16/98]

Thermo Environmental Instruments, Incorporated Model 605 "CAPS" SamplerManual Reference Method: **RFPS-1098-123**

"Thermo Environmental Instruments, Incorporated Model 605 "CAPS" Computer Assisted Particle Sampler," configured as a PM_{2.5} reference method and operated with software version 1.02A, for 24-hour continuous sample periods, in accordance with the Model 605 Instruction Manual and with the requirements and sample collection filters specified in 40 CFR Part 50, Appendix L.

[Federal Register: Vol 63, page 58036, 10/29/98]

SULFUR DIOXIDE

Reference Method for SO₂ (Pararosaniline Method)Manual Reference Method: **40 CFR Part 50, Appendix A**

Reference Method for the Determination of Sulfur Dioxide in the Atmosphere (Pararosaniline Method)

[Federal Register: Vol 47, page 54899, 12/06/82 and Vol 48, 17355, 04/22/83]

Pararosaniline Method for SO₂ - Technicon IManual Equivalent Method: **EQS-0775-001**

"Pararosaniline Method for the Determination of Sulfur Dioxide in the Atmosphere-Technicon I Automated Analysis System"

[Federal Register: Vol 40, page 34024, 08/13/75]

Pararosaniline Method for SO₂ - Technicon IIManual Equivalent Method: **EQS-0775-002**

"Pararosaniline Method for the Determination of Sulfur Dioxide in the Atmosphere-Technicon II Automated Analysis System"

[Federal Register: Vol 40, page 34024, 08/13/75]

Advanced Pollution Instrumentation, Inc. Model 100 SO₂ AnalyzerAutomated Equivalent Method: **EQSA-0990-077**

"Advanced Pollution Instrumentation, Inc. Model 100 Fluorescent SO₂ Analyzer," operated on the 0-0.1 ppm¹, the 0-0.2 ppm¹, the 0-0.5 ppm, or the 0-1.0 ppm range with a 5-micron TFE filter element installed in the rear-panel filter assembly, either a user- or vendor-supplied vacuum pump capable of providing 20 inches of mercury vacuum at 2.5 L/min, with or without any of the following options: Internal Zero/Span; Pump Pack; Rack Mount With Slides; RS-232 Interface; Status Output; TFE Zero/Span Valves; Zero Air Scrubber; Dual Range.²

[Federal Register: Vol. 55, page 38149, 09/17/90]

Advanced Pollution Instrumentation, Inc. Model 100A SO₂ AnalyzerAutomated Equivalent Method: **EQSA-0495-100**

"Advanced Pollution Instrumentation, Inc. Model 100A Sulfur Dioxide Analyzer," operated on any full scale range between 0-50 ppb¹ and 0-1000 ppb, at any temperature in the range of 5 to 40 degrees C, with a 5-micron TFE filter element installed in the filter assembly, with either the vendor-supplied internal pump or a user- or vendor-supplied external vacuum pump capable of maintaining an absolute pressure of 35 cm (14 inches) of mercury (or less) at 1.0 standard liter per minute flow rate, with the following software

settings: Dynamic zero: OFF or ON; Dynamic span: OFF; AutoCal: ON or OFF; Dual range: ON or OFF; Autorange: ON or OFF; Temp/pressure compensation: ON; dilution factor: 1.0; and with or without any of the following options:²

| | | |
|--------------------------------|--|-------------------------------|
| Rack mount with chassis slides | Rack mount without slides, ears only | Fluorocarbon zero/span valves |
| Internal zero/span (IZS) | 4-20 mA, isolated outputs | External pump |
| Status outputs | Rack mount for external pump with tray | RS-232 output |
| Combustion Filter | | |

SO₂ Permeation tube, uncertified, 0.4 ppm @ 0.7 L/min

SO₂ Permeation tube, certified, 0.4 ppm @ 0.7 L/min

SO₂ Permeation tube, uncertified, 0.8 ppm @ 0.7 L/min

SO₂ Permeation tube, certified, 0.8 ppm @ 0.7 L/min

[Federal Register: Vol. 60, page 17061, 04/04/95]

ASARCO Model 500 SO₂ Monitor

Automated Equivalent Method: EQSA-0877-024

"ASARCO Model 500 Sulfur Dioxide Monitor," operated on a 0-0.5 ppm range; or "ASARCO Model 600 Sulfur Dioxide Monitor," operated on a 0-1.0 ppm range. (Both models are identical except for the range.) NOTE: This method is not now commercially available.

[Federal Register: Vol 42, page 44264, 09/02/77 and Vol 44, page 67522, 11/26/79]

Beckman Model 953 Fluorescent Ambient SO₂ Analyzer

Automated Equivalent Method: EQSA-0678-029

"Beckman Model 953 Fluorescent Ambient SO₂ Analyzer," operated on a range of either 0-0.5 or 0-1.0 ppm, with a time constant setting of 2, 2.5, or 3 minutes, a 5 to 10 micron membrane filter element installed in the rear-panel filter assembly, with or without any of the following options: Remote Operation Kit, Catalog No. 641984; Digital Panel Meter, Catalog No. 641710; Rack Mount Kit, Catalog No. 641709; Panel Mount Kit, Catalog No. 641708.

[Federal Register: Vol 43, page 35995, 08/14/78]

Bendix Model 8303 Sulfur Analyzer

Automated Equivalent Method: EQSA-1078-030

"Bendix Model 8303 Sulfur Analyzer," operated on a range of either 0-0.5 or 0-1.0 ppm, with a Teflon filter installed on the sample inlet of the H₂S scrubber assembly.

[Federal Register: Vol 43, page 50733, 10/31/78]

Columbia Scientific Industries Model 5700 SO₂ Analyzer

Automated Equivalent Method: EQSA-0494-095

"Columbia Scientific Industries Model 5700 Sulfur Dioxide Analyzer", operated with software version 1.0 on any full scale range between 0-250 ppb¹ and 0-1000 ppb, at any integration time setting from 20 to 99 seconds, at any temperature in the range of 15°C to 30°C, at any AC line voltage in the range of 105 to 130 volts, and with or without any of the following options:

| | | |
|--------------------------------------|-------------------------------|-----------------------------|
| 964-0121 Alarm Relay Contacts | 964-0125 Dual Current Outputs | 964-0131 Rack Mount |
| 964-0122 Input Solenoids | 964-0126 Printer | 964-0012 Single Headed Pump |
| 964-0124 Dual Analog Voltage Outputs | | |

[Federal Register: Vol 59, page 18818, 04/20/94]

Dasibi Model 4108 U.V. Fluorescence SO₂ Analyzer

Automated Equivalent Method: EQSA-1086-061

"Dasibi Model 4108 U.V. Fluorescence SO₂ Analyzer," operated with a range of 0-100 ppb¹, 0-200 ppb¹, 0-500 ppb, or 0-1000 ppb, with a Teflon-coated particulate filter and continuous hydrocarbon removal system, with or without any of the following options: Rack Mounting Brackets And Slides; RS-232-C Interface; Temperature Correction.

[Federal Register: Vol 51, page 32244, 09/10/86]

DKK Corp. Model GFS-32 U.V. Fluorescent SO₂ Analyzer

Automated Equivalent Method: EQSA-0701-115

"DKK Corporation Model GFS-32 Ambient Air SO₂ Ultraviolet Fluorescent Analyzer, operated within the 0.000 to 0.500 ppm range in the temperature range of 20°C to 30°C.

[Federal Register: Vol 62, page 44007, 08/18/97]

Environnement S.A. Model AF21M SO₂ Analyzer

Automated Equivalent Method: EQSA-0292-084

"Environnement S.A. Model AF21M Sulfur Dioxide Analyzer," operated on a range of 0-0.5 ppm with a response time coefficient setting of 01, a Teflon filter installed in the rear-panel filter assembly, and with or without any of the following options: Rack Mount/Slides; RS-232-C Interface.

[Federal Register: Vol 57, page 5444, 02/14/92]

Horiba Models APSA-360, APSA-360-CE, or APSA-360A-CE SO₂ Monitors

Automated Equivalent Method: EQSA-0197-114

"Horiba Instruments, Inc. Model APSA-360 and Model APSA-360-CE Ambient Sulfur Dioxide Monitor," operated with a full scale range of 0 - 0.50 ppm, at any temperature in the range of 5 °C to 40 °C, with a Line Setting of "MEASURE", an Analog Output Setting of "MOMENTARY VALUE", and with or without any of the following options:² 1) Rack Mounting Plate and Side Rails, 2) RS-232 Communications Port, and 3) Internal zero gas and span gas generator.

"Horiba Instruments, Inc. Model APSA-360A-CE Ambient Sulfur Dioxide Monitor," operated with one of the following measurement ranges: 0-0.05 ppm, 0-0.1 ppm, 0-0.2 ppm, 0-0.5 ppm or 0-1.0 ppm; with selectable time constants from 10 to 300 seconds; at any temperature in the range of 5 °C to 40 °C; and with or without the optional internal zero gas and span gas generator.

[Federal Register: Vol 63, page 31992, 06/11/98]

Lear Siegler Model AM2020 SO₂ MonitorAutomated Equivalent Method: **EQSA-0486-049**

"Lear Siegler Model AM2020 Ambient SO₂ Monitor," operated on a range of either 0-0.5 or 0-1.0 ppm, at a wavelength of 299.5 nm, with a 5 minute integration period, over any 10°C temperature range between 20°C and 45°C, with or without the automated zero and span correction feature. [Federal Register: Vol 45, page 79574, 12/01/80 and Vol 46, page 9997, 01/30/81]

Lear Siegler Model SM1000 SO₂ MonitorAutomated Equivalent Method: **EQSA-1275-005**

"Lear Siegler Model SM1000 SO₂ Ambient Monitor," operated on the 0-0.5 ppm range, at a wavelength of 299.5 nm, with the "slow" (300 second) response time, with or without any of the following options: SM-1 Internal Zero/Span; SM-2 Span Timer Card; SM-3 0-0.1 Volt Output; SM-4 0-5 Volt Output; SM-5 Alternate Sample Pump; SM-6 Outdoor Enclosure. [Federal Register: Vol 41, page 3893, 01/27/76; Vol 41, page 32946, 08/06/76; Vol 42, page 13044, 03/08/77; Vol 45, page 1147, 01/04/80]

Meloy Model SA185-2A SO₂ AnalyzerAutomated Equivalent Method: **EQSA-1275-006**

"Meloy Model SA185-2A Sulfur Dioxide Analyzer," operated on the 0-0.5 ppm range, with or without any of the following options:

| | | |
|-------------------------------|--|--|
| S-1 Linearized Output | S-18 Rack Mount Conversion | S-24 Dual Range Linearized Output |
| S-2 Modified Recorder Output | S-18A Rack Mount Conversion | S-33 Remote Range Control And Status (Signals) |
| S-5 Teflon-Coated Block | S-21 Front Panel Digital Volt Meter | S-34 Remote Control |
| S-6A Reignite Timer Circuit | S-22 Remote Zero/Span Control And Status (Timer) | S-35 Front Panel Digital Meter With BCD Output |
| S-7 Press To Read | S-22A Remote Zero/Span Control | S-36 Dual Range Log-Linear Output |
| S-11A Manual Zero And Span | S-23 Automatic Zero Adjust | S-38 Sampling Mode Status |
| S-11B Automatic Zero And Span | S-23A Automatic/Manual Zero Adjust | |
| S-13 Status Lights | | |
| S-14 Output Booster Amplifier | | |
| S-14B Line Transmitter Board | | |

or operated on the 0-1.0 ppm range with either option S-36 or options S-1 and S-24, with or without any of the other options.

[Federal Register: Vol 41, page 3893, 01/27/76 and Vol 43, page 38088, 08/25/78]

Meloy Model SA285E SO₂ AnalyzerAutomated Equivalent Method: **EQSA-1078**

"Meloy Model SA285E Sulfur Dioxide Analyzer," operated on the following ranges and time constant switch positions:

| | | | | |
|------------------------|-------------------|--------------------|--------------|--------------|
| Range, ppb: | 0-50 ¹ | 0-100 ¹ | 0-500 | 0-1000 |
| Time Constant Setting: | 1 or 10 | 1 or 10 | off, 1 or 10 | off, 1 or 10 |

The analyzer may be operated at temperatures between 10°C and 40°C and at line voltages between 105 and 130 volts, with or without any of the following options:

| | | |
|--|---|--|
| S-5 Teflon Coated Block | S-22B Remote Zero/Span Control And Status (Pulse) | S-30 Auto Reignite |
| S-14B Line Transmitter Board | S-23 Auto Zero Adjust | S-32 Remote Range Control And Status |
| S-18 Rack Mount Conversion | S-23A Auto/Manual Zero Adjust | S-35 Front Panel Digital Meter With BCD Output |
| S-18A Rack Mount Conversion | S-25 Press To Read | S-37 Temperature Status Lights |
| S-21 Front Panel Digital Meter | S-26 Manual Zero And Span | S-38 Sampling Mode Status |
| S-22 Remote Zero/Span Control And Status (Timer) | S-27 Auto Manual Zero/Span | |
| S-22A Remote Zero/Span Control | S-28 Auto Range And Status | |

[Federal Register: Vol 43, page 50733, 10/31/78]

Meloy Model SA 700 Fluorescence Sulfur Dioxide AnalyzerAutomated Equivalent Method: **EQSA-0580-046**

"Meloy Model SA 700 Fluorescence Sulfur Dioxide Analyzer," operated on the 0-250 ppb¹, the 0-500 ppb, or the 0-1000 ppb range with a time constant switch position of either 2 or 3. The analyzer may be operated at temperatures between 20°C and 30°C and at line voltages between 105 and 130 volts, with or without any of the following options: FS-1 Current Output; FS-2 Rack Mount Conversion; FS-2A Rack Mount Conversion; FS-2B Rack Mount Conversion; FS-3 Front Panel Mounted Digital Meter; FS-5 Auto/Manual Zero/Span With Status; FS-6 Remote/Manual Zero/Span With Status; FS-7 Auto Zero Adjust.

[Federal Register: Vol 45, page 31488, 05/13/80]

Monitor Labs Model 8450 Sulfur MonitorAutomated Equivalent Method: **EQSA-0876-013**

"Monitor Labs Model 8450 Sulfur Monitor", operated on a range of either 0-0.5 or 0-1.0 ppm, with a 5 second time constant, model 8740 hydrogen sulfide scrubber in the sample line, with or without any of the following options: BP Bipolar Signal Process; IZS Internal Zero/Span Module; V Zero/Span Valves; CLO Current Loop Output; TF TFE Sample Particulate Filter; VT Zero/Span Valves And Timer; DO Status Remote Interface.

[Federal Register: Vol 41, page 36245, 08/27/76 and Vol 44, page 33476, 06/11/79]

Monitor Labs/Lear Siegler Model 8850 SO₂ AnalyzerAutomated Equivalent Method: **EQSA-0779-039**

"Monitor Labs or Lear Siegler Model 8850 Fluorescent SO₂ Analyzer," operated on a range of either 0-0.5 or 0-1.0 ppm, with an internal time constant setting of 55 seconds, a TFE sample filter installed on the sample inlet line, with or without any of the following options: 03A Rack; 03B Slides; 05A Valves Zero/Span; 06A IZS Internal Zero/Span Source; 06B.C.D NIST Traceable Permeation Tubes; 08A Pump; 09A Rack Mount For Option 08A; 010 Status Output W/Connector; 013 Recorder Output Options; 014 DAS Output Options; 017 Low Flow Option; 018 Kicker.

[Federal Register: Vol 44, page 44616, 07/30/79]

Monitor Labs/Lear Siegler Model 8850S SO₂ AnalyzerAutomated Equivalent Method: **EQSA-0390-075**

"Monitor Labs or Lear Siegler Model 8850S SO₂ Analyzer," operated on a range of either 0-0.5 or 0-1.0 ppm.

[Federal Register: Vol 55, page 5264, 02/14/90]

Monitor Labs/Lear Siegler Model ML9850,Automated Equivalent Method: **EQSA-0193-092****Monitor Labs Model ML9850B, or Wedding & Associates Model 1040 SO₂ Analyzers**

"Lear Siegler Measurement Controls Corporation or Monitor Labs Model ML9850, Monitor Labs Model ML9850B, or Wedding & Associates, Inc. Model 1040 Sulfur Dioxide Analyzers," operated on any full scale range between 0-0.050 ppm¹ and 0-1.0 ppm, at any temperature in the range of 15°C to 35°C, with the service switch on the secondary panel set to the *In* position; with the following menu choices selected: Range: *0.05 ppm to 1.0 ppm*; Over-ranging: *Enabled or Disabled*; Background: *Not Disabled*; Calibration: *Manual or Timed*; Diagnostic Mode: *Operate*; Filter Type: *Kalman*; Pres/Temp/Flow Comp: *On*; Span Comp: *Disabled*; and as follows: **Model ML9850** - with a five-micron Teflon[®] filter element installed internally, with the 50-pin I/O board installed on the rear panel configured at any of the following output range settings: Voltage, 0.1 V, 1 V, 5 V, 10 V; Current, 0-20 mA, 2-20 mA, 4-20 mA; and with or without any of the following options: Valve Assembly for External Zero/Span (EVS); Rack Mount Assembly; Internal Floppy Disk Drive. **Models ML9850B and 1040** - with either a vendor-supplied or equivalent user supplied five-micron Teflon[®] filter, zero air scrubber, and exhaust pump, and with or without any of the following options: Valve Assembly for External Zero/Span (EVS); Rack Mount Assembly; 50-pin I/O board; Exhaust Scrubber; Internal Zero/Span Assembly (IZS); hinged, fold-down front panel.

[Federal Register: Vol 58, page 6964, 02/03/93]

Opsis Model AR 500 and System 300 Open Path Ambient Air Monitoring Systems for SO₂Automated Equivalent Method: **EQSA-0495-101**

"Opsis Model AR 500 System" or "System 300" Open Path (long path) Ambient Air Monitoring Systems, configured for measuring SO₂, with one detector and movable grating, operated with a measurement range of 0 to 0.5 ppm or 0 to 1.0 ppm, an installed monitoring path length between 20 and 500 meters (or 20 and 1000 meters with the ER 150 option, AR 500 System only), xenon lamp type B (150 watt), fiber optic cable length between 3 to 20 meters; operating within an ambient air temperature range of -50 to +50°C, an analyzer temperature range of 20 to 30°C, a measurement (integrating) time setting between 30 and 120 seconds (0 min:30 sec. to 2 min:00 sec.), and with a complete cycle time of not more than 200 seconds (3 min, 20 sec.). Under this method designation, the Model AR 500 System or System 300 consists of: AR 500 opto-analyser; emitter EM 110 and receiver RE 110 (together identified as ER 110); optic fibre cable OF60-S; power supply PS 150; OPSIS operational software, version 7.0 or 7.1; and initial on-site installation, setup, and limited operator training.²

Optional components that can be used with the Model AR 500 only, in addition to or as alternative to corresponding components listed above:

AR 503 opto-analyser configured as Model AR 500 (only the center detector active, sequential monitoring)

Emitter/receiver ER 150 (for monitoring path lengths up to 1 kilometer)

Transceiver ER 130 and Retroreflector RE 090 with:
7 prisms (max. monitoring path length 150 meters) or
12 prisms (max. monitoring path length 250 meters)

Receiver RE 130

Xenon lamp type A (higher short-wavelength UV output)
Optic fibre cable OF60-R (low-loss for short wavelengths)

Multiplexers MX 004 and MX 024

Dataloggers DL 010 and DL 016

Analogue and digital input/output cards AO 008, AI 016,
and DI 032

Analogue and digital isolation cards IA 008, ID 008,
OA 008, and OD 008,

Window heaters HF 110 and HF 150

Mirror heaters HM 110 and HM 150

Auto calibration unit CU 007

Software packages IO 80 (for the analogue and digital input/output adapters), DL10 and DL16 (for data loggers), COMVISION, and STAT 500;

Recommended calibration and accuracy audit components (or equivalent) for either Model AR 500 or System 300:

Wavelength calibration lamp CA 004

Calibration bench CB 100

Receiver unit RE 060 (two required)

Calibration unit CA 150, with same type lamp as used in the monitoring path emitter

Power supply PS 150 for calibration unit CA 150

Calibration cells CC 001-X, where X represents various cell lengths from 1 to 900 mm

Special calibration cells CC 110 or CC 150 (for mounting directly on receiver)

Light meter LM 010.

[Federal Register: Vol. 60, page 21518, 05/02/1995]

Philips PW9755 SO₂ AnalyzerAutomated Equivalent Method: **EQSA-0676-010**

"Philips PW9755 SO₂ Analyzer," consisting of the following components: PW9755/02 SO₂ Monitor with PW9741/00 SO₂ Source, PW9721/00 Filter Set SO₂, PW9711/00 Electrolyte SO₂, PW9750/00 Supply Cabinet, PW9750/10 Supply Unit/ Coulometric, or PW9731/00 Sampler or PW9731/20 Dust Filter (or vendor-approved alternate particulate filter); operated with a 0-0.5 ppm range and with a reference voltage setting of 760 millivolts; with or without any of the following options: PW9750/30 Frame For MTT; PW9752/00 Air Sampler Manifold; PW9753/00 Mounting Rack For Accessories; PW9750/41 Control Clock 60 Hz; PW9754/00 Air Distributor. [Federal Register: Vol 41, page 26252, 6/25/76; Vol 41, page 46019, 10/19/76; Vol 42, page 28571, 6/03/77]

Philips PW9700 SO₂ Analyzer*Automated Equivalent Method: EQSA-0876-011*

"Philips PW9700 SO₂ Analyzer," consisting of the following components: PW9710/00 Chemical Unit with PW9711/00 Electrolyte SO₂, PW9721/00 Filter Set SO₂, PW9740/00 SO₂ Source; PW9720/00 Electrical Unit; PW9730/00 Sampler Unit (or vendor-approved alternate particulate filter); operated with a 0-0.5 ppm range and with a reference voltage of 760 millivolts.

[Federal Register: Vol 41, page 34105, 08/12/76]

Thermo Electron Model 43 SO₂ Analyzer*Automated Equivalent Method: EQSA-0276-009*

"Thermo Electron Model 43 Pulsed Fluorescent SO₂ Analyzer," equipped with an aromatic hydrocarbon cutter and operated on a range of either 0-0.5 or 0-1.0 ppm, with or without any of the following options: 001 Rack Mounting For Standard 19 Inch Relay Rack; 002 Automatic Actuation Of Zero And Span Solenoid Valves; 003 Type S Flash Lamp Power Supply; 004 Low Flow.

[Federal Register: Vol 41, page 8531, 02/27/76; Vol 41, page 15363, 04/12/76; Vol 42, page 20490, 04/20/77;

Vol 44, page 21861, 04/12/79; Vol 45, page 2700, 01/14/80; Vol 45, page 32419, 05/16/80]

Thermo Environmental Instruments, Inc. Models 43A, 43B, 43C Analyzers *Automated Equivalent Method: EQSA-0486-060*

"Thermo Electron or Thermo Environmental Instruments, Inc. Model 43A or 43B Pulsed Fluorescence SO₂ Analyzer," operated on the 0-0.1 ppm¹, the 0-0.2 ppm¹, the 0-0.5 ppm, or the 0-1.0 ppm range, with either a high or a low time constant setting (Model 43A) and with or without any of the following options:²

| | | |
|-------------------------------------|-------------------------------------|---|
| 001 Teflon Particulate Filter | 004 High Flow Rate (1 LPM) | 007 Remote Activation Of Zero/Span Valves |
| 002 19" Rack Mounting Configuration | 005 Current Output | 008 RS-232 Interface (Model 43B) |
| 003 Internal Zero/Span Valves | 006 Internal Permeation Span Source | 009 Pressure/Temperature Compensation (Model 43B) |

"Thermo Environmental Instruments, Inc. Model 43C Pulsed Fluorescence SO₂ Analyzer," operated on any measurement range between 0-50 ppb¹ and 0-1000 ppb, with any time average setting from 10 to 300 seconds, with temperature and/or pressure compensation on or off, operated at temperatures between 20 °C and 30 °C, with or without any of the following options:²

| | |
|---|--|
| 43C-001 Teflon particulate filter | 43C-005 4-20 mA current output |
| 43C-002 Rack mounts | 43C-006 Internal permeation span source |
| 43C-003 Internal zero/span and sample solenoid valves | 43C-007 Remote activation of zero/span and sample valves |
| 43C-004 High flow rate (0.5-1.0 LPM) | 43C-008 RS-232/485 interface |

[Federal Register: Vol 51, page 12390, 04/10/86]

OZONE**Advanced Pollution Instrumentation, Inc. Model 400/400A Ozone Analyzer** *Automated Equivalent Method: EQOA-0992-087*

"Advanced Pollution Instrumentation, Inc. Model 400 or 400A Ozone Analyzer," operated on any full scale range between 0-100 ppb* and 0-1000 ppb, with any range mode (Single, Dual, or AutoRange), at any ambient temperature in the range of 5°C to 40°C, with the dynamic zero and span adjustment feature (some Model 400 units only) set to OFF, with a 5-micron TFE filter element installed in the rear-panel filter assembly, and with or without any of the following options: Zero/Span Valve option, Internal Zero/Span (IZS) option, IZS ozone generator reference feedback option, standard serial port or Multi-drop RS-232, digital status outputs, analog outputs: 100 mV, 1 V, 5 V, 10 V, 4-20 mA current loop, optional metal wool ozone scrubber, optional external sample pump, optional 47 mm diameter filter, optical bench heater, rack mount with slides.

[Federal Register: Vol 63, page 31992, 06/11/98]

Beckman Model 950A Ozone Analyzer*Automated Reference Method: RFOA-0577-020*

"Beckman Model 950A Ozone Analyzer," operated on a range of 0-0.5 ppm and with the "SLOW" (60 second) response time with or without any of the following options: Internal Ozone Generator; Computer Adaptor Kit; Pure Ethylene Accessory.

[Federal Register: Vol 42, page 28571, 06/03/77]

Bendix or Combustion Engineering Model 8002 Ozone AnalyzerAutomated Reference Method: **RFOA-0176-007**

"Bendix or Combustion Engineering Model 8002 Ozone Analyzer", operated on the 0-0.5 ppm range, with a 40 second time constant, with or without any of the following options: Rack Mounting With Chassis Slides; Rack Mounting Without Chassis Slides; Zero And Span Timer; Ethylene/CO₂ Blend Reactant Gas.

[Federal Register: Vol 41, page 5145, 02/04/76 and Vol 45, page 18474, 03/21/80]

Columbia Scientific Industries Model 2000 Ozone MeterAutomated Reference Method: **RFOA-0279-036**

"Columbia Scientific Industries Model 2000 Ozone Meter," when operated on the 0-0.5 ppm range with either AC or battery power: The BCA 952 battery charger/AC adapter M952-0002 (115V) or M952-0003 (230V) is required for AC operation; an internal battery M952-0006 or 12 volt external battery is required for portable non-AC powered operation.

[Federal Register: Vol 44, page 10429, 02/20/79]

Dasibi Models 1003-AH, 1003-PC, or 1003-RS Ozone AnalyzersAutomated Equivalent Method: **EQOA-0577-019**

"Dasibi Model 1003-AH, 1003-PC, or 1003-RS Ozone Analyzer," operated on a range of either 0-0.5 or 0-1.0 ppm, with or without any of the following options: Adjustable Alarm; Aluminum Coated Absorption Tubes; Integrated Output; Vycor-Jacketed U.V. Source Lamp; BCD Digital Output; Rack Mounting Ears And Slides; 0-10 mV, 0-100 mV, 0-1 V, Or 0-10 V; Glass (Pyrex) Absorption Tubes; Teflon-based Solenoid Valve; Analog Output.

[Federal Register: Vol 42, page 28571, 06/03/77]

Dasibi Models 1008-AH, 1008-PC, or 1008-RS Ozone AnalyzersAutomated Equivalent Method: **EQOA-0383-056**

"Dasibi Model 1008-AH, 1008-PC, or 1008-RS Ozone Analyzer," operated on a range of either 0-0.5 or 0-1.0 ppm, with or without any of the following options: Aluminum Coated Absorption Tubes; BCD Digital Output; RS232 Interface; Glass (Pyrex) Absorption Tubes; Vycor-Jacketed U.V. Source Lamp; Ozone Generator; Teflon-based Solenoid Valve; Photometer Flow Restrictor (2 LPM); 4-20 mA, Isolated, Or Dual Analog Outputs; Rack Mounting Brackets Or Slides; 20 Second Update Software.

[Federal Register: Vol 48, page 10126, 03/10/83]

EnviroNics Series 300 Ozone AnalyzerAutomated Equivalent Method: **EQOA-0990-078**

"EnviroNics Series 300 Computerized Ozone Analyzer," operated on the 0-0.5 ppm range, with the following parameters entered into the analyzer's computer system: Absorption Coefficient = 308 ± 4 ; Flush Time = 3; Integration Factor = 1; Offset Adjustment = 0.025 ppm; Ozone Average Time = 4; Signal Average = 0; Temp/Press Correction = On; and with or without the RS-232 Serial Data Interface.

[Federal Register: Vol 55, page 38386, 09/18/90]

Environnement S.A. Model O₃41M UV Ozone AnalyzerAutomated Equivalent Method: **EQOA-0895-105**

"Environnement S.A. Model O₃41M UV Photometric Ozone Analyzer," operated on a full scale range of 0 - 500 ppb, at any temperature in the range of 15 °C to 35 °C, with the response time set to 50 seconds, and with or without any of the following options:² Internal Ozone Generator; Span External Control; RS232-422 Serial Interface; Internal Printer.

[Federal Register: Vol. 60, page 39382, 08/02/95]

Horiba Instruments Models APOA-360 and APOA-360-CE Ozone MonitorAutomated Equivalent Method: **EQOA-0196-112**

"Horiba Instruments, Inc. Model APOA-360 or APOA-360-CE Ambient Ozone Monitor," operated with a full scale range of 0 - 0.50 ppm, at any temperature in the range of 10°C to 40°C, with a Line Setting of "MEASURE", and an Analog Output of "MOMENTARY VALUE", and with or without any of the following options:² 1) Rack Mounting Plate and Side Rails 2) RS-232 Communications Port, and 3) Optional Internal Zero/Span Check.

[Federal Register: Vol. 61, page 11404, 03/20/96]

McMillan (MEC) Models 1100-1, 1100-2, and 1100-3 Ozone MetersAutomated Reference Method: **RFOA-1076-014**

"MEC Model 1100-1 Ozone Meter,"

Automated Reference Method: **RFOA-1076-015**

"MEC Model 1100-2 Ozone Meter,"

Automated Reference Method: **RFOA-1076-016**

"MEC Model 1100-3 Ozone Meter,"

operated on a 0-0.5 ppm range, with or without any of the following options: 0011 Rack Mounting Ears; 0026 Alarm Set Feature; 0012 Instrument Bail; 0033 Local-Remote Sample; Zero, Span Kit Blend Feature; 0016 Chassis Slide Kit; 0040 Ethylene/CO₂.

[Federal Register: Vol 41, page 46647, 10/22/76 and Vol 42, page 30235, 06/13/77]

Meloy Model OA325-2R Ozone AnalyzerAutomated Reference Method: **RFOA-1075-003**

"Meloy Model OA325-2R Ozone Analyzer," operated with a scale range of 0-0.5 ppm, with or without any of the following options: 0-4 Output Booster Amplifier; 0-18 Rack Mount Conversion; 0-18A Rack Mount Conversion.

[Federal Register: Vol 40, page 54856, 11/26/75]

Meloy Model OA350-2R Ozone AnalyzerAutomated Reference Method: **RFOA-1075-004**

"Meloy Model OA350-2R Ozone Analyzer," operated with a scale range of 0-0.5 ppm, with or without any of the following optic 0-2 Automatic Zero And Span; 0-3 Remote Control Zero And Span; 0-4 Output Booster Amplifier; 0-18 Rack Mount Conversion; 0-18A Rack Mount Conversion. [Federal Register: Vol 40, page 54856, 11/26/75]

Monitor Labs Model 8410E Ozone AnalyzerAutomated Reference Method: **RFOA-1176-017**

"Monitor Labs Model 8410E Ozone Analyzer," operated on a range of 0-0.5 ppm with a time constant setting of 5 seconds, with or without any of the following options: DO Status Outputs; ER Ethylene Regulator Assembly; V TFE Zero/Span Valves; TF TFE Sample Particulate Filter; VT TFE Zero/Span Valves And Timer. [Federal Register: Vol 41, page 53684, 12/08/76]

Monitor Labs/Lear Siegler Model 8810 Ozone AnalyzerAutomated Equivalent Method: **EQOA-0881-053**

"Monitor Labs or Lear Siegler Model 8810 Photometric Ozone Analyzer," operated on a range of either 0-0.5 or 0-1.0 ppm, with selectable electronic time constant settings from 20 through 150 seconds, with or without any of the following options: 05 Pressure Compensation; 06 Averaging Option; 07 Zero/Span Valves; 08 Internal Zero/Span (Valve And Ozone Source); 09 Status; 10 Particulate Filter; 15 through 20 DAS/REC Output. [Federal Register: Vol 46, page 52224, 10/26/81]

Monitor Labs/Lear Siegler Models ML9810, ML9811, or ML9812,Automated Equivalent Method: **EQOA-0193-091****Monitor Labs Model ML9810B, or Wedding & Associates Model 1010 Ozone Analyzers**

"Lear Siegler Measurement Controls Corporation Model ML9810 or Monitor Labs Models ML9810, ML9811, or ML9812, Monitor Labs Model 9810B, or Wedding & Associates, Inc. Model 1010 Ozone Analyzers," operated on any full scale range between 0-0.05 ppm¹ and 0-1.0 ppm, at any temperature in the range of 15°C to 35°C, with the service switch on the secondary panel set to the *In* position; with the following menu choices selected: Range: *0.05 ppm to 1.0 ppm*; Over-ranging: *Enabled or Disabled*; Calibration: *Manual or Timed*; Diagnostic Mode: *Operate*; Filter Type: *Kalman*; Pres/Temp/Flow Comp: *On*; Span Comp: *Disabled*; and as follows: **Models ML9810, ML9811, and ML9812** - with a five-micron Teflon® filter element installed internally, with the 50-pin I/O board installed on the rear panel configured at any of the following output range settings: Voltage, 0.1 V, 1 V, 5 V, 10 V; Current, 0-20 mA, 2-20 mA, 4-20 mA; and with or without any of the following options: Valve Assembly for External Zero/Span (EVS); Rack Mount Assembly; Internal Floppy Disk Drive. **Models ML9810B and 1010** - with either a vendor-supplied or equivalent user-supplied five micron Teflon® filter and exhaust pump, and with or without any of the following options: Valve Assembly for External Zero/Span (EVS); Rack Mount Assembly; 50-pin I/O board; Internal Zero/Span Assembly (IZS); hinge, fold-down front panel. [Federal Register: Vol 58, page 6964, 02/03/93]

Opsis Model AR 500 and System 300 Open Path Ambient Air Monitoring Systems for OzoneAutomated Equivalent Method: **EQOA-0495-103**

"Opsis Model AR 500 System" or "System 300" Open Path (long path) Ambient Air Monitoring Systems, configured for measuring O₃, with one detector and moveable grating, operated with a measurement range of 0 to 0.5 ppm, an installed monitoring path length between 20 and 500 meters (or 20 and 1000 meters with the ER 150 option, AR 500 System only), xenon lamp type B (150 watt), fiber optic cable length between 3 to 20 meters; operating within an ambient air temperature range of -50 to +50°C, an analyzer temperature range of 20 to 30°C, a measurement (integrating) time setting between 30 and 120 seconds (0 min:30 sec. to 2 min:00 sec.), and with a complete cycle time of not more than 200 seconds (3 min, 20 sec.). Under this method designation, the Model AR 500 System or System 300 consists of: AR 500 opto-analyser; emitter EM 110 and receiver RE 110 (together identified as ER 110); optic fibre cable OF60-S; power supply PS 150, OPSIS operational software, version 7.0 or 7.1; and initial on-site installation, setup, and limited operator training.²

Optional components that can be used with the Model AR 500 only, in addition to or as alternative to corresponding components listed above:

AR 503 opto-analyzer configured as Model AR 500 (only the center detector active, sequential monitoring)

Emitter/receiver ER 150 (for monitoring path lengths up to 1 kilometer)

Transceiver ER 130 and Retroreflector RE 090 with:
7 prisms (max. monitoring path length 150 meters) or
12 prisms (max. monitoring path length 250 meters)

Receiver RE 130

Optic fibre cable OF60-R (low-loss for short wavelengths)

Multiplexers MX 004 and MX 024

Dataloggers DL 010 and DL 016

Analogue and digital input/output cards AO 008, AI 016, and DI 032

Analogue and digital isolation cards IA 008, ID 008, OA 008, and OD 008.

Window heaters HF 110 and HF 150

Mirror heaters HM 110 and HM 150

Auto calibration unit CU 007

Software packages IO 80 (for the analogue and digital input/output adapters), DL10 and DL16 (for data loggers), ComVision, and STAT 500:

Recommended calibration and accuracy audit components (or equivalent) for either Model AR 500 or System 300:

Wavelength calibration lamp CA 004

Calibration bench CB 100

Receiver unit RE 060 (two required)

Calibration unit CA 150, with same type lamp as used in the monitoring path emitter

Power supply PS 150 for calibration unit CA 150

Calibration cells CC 001-X, where X represents various cell lengths from 1 to 900 mm

Special calibration cells CC 110 or CC 150 (for mounting directly on receiver)

Ozone generator OC 500

Light meter LM 010.

Federal Register: Vol. 60, page 21518, 05/02/1995]

PCI Ozone Corporation Model LC-12 Ozone Analyzer

Automated Equivalent Method: EQOA-0382-055

"PCI Ozone Corporation Model LC-12 Ozone Analyzer," operated on a range of 0-0.5 ppm.

[Federal Register: Vol 47, page 13572, 03/31/82]

Philips PW9771 03 Analyzer

Automated Equivalent Method: EQOA-0777-023

"Philips PW9771 03 Analyzer," consisting of the following components: PW9771/00 03 Monitor with PW9724/00 Disc.-Set; PW9750/00 Supply Cabinet; PW9750/20 Supply Unit operated on a range of 0-0.5 ppm, with or without any of the following accessories: PW9732/00 Sampler Line Heater; PW9750/30 Frame For MTT; PW9750/41 Control Clock 60 Hz; PW9733/00 Sampler; PW9752/00 Air Sampler Manifold. *[Federal Register: Vol 42, page 38931, 08/01/77; Vol 42, page 57156, 11/01/77]*

Thermo Electron/Thermo Environmental Instruments Models 49, 49C

Automated Equivalent Method: EQOA-0880-047

"Thermo Electron or Thermo Environmental Instruments, Inc. Model 49 U.V. Photometric Ambient O₃ Analyzer" operated on a measurement range of either 0-0.5 or 0-1.0 ppm with or without any of the following options:

49-001 Teflon Particulate Filter; 49-002 19 Inch Rack Mount; 49-100 Internal Ozone Generator for Zero, Precision, and Level 1 Span Check; 49-103 Internal Ozone Generator for Zero, Precision, and Level 1 Span Checks With Remote Activation;

49-488 GPIB (General Purpose Interface Bus) IEEE-488

"Thermo Electron or Thermo Environmental Instruments, Inc. Model 49C U.V. Photometric Ambient O₃ Analyzer" operated on any measurement range between 0-0.05¹ to 1.0 ppm with any time average setting between 10 and 300 seconds, with the temperature and/or pressure compensation on or off, with or without any of the following options: ²

100 Teflon particulate filter

420 Internal Zero Air Scrubber

200 Carrying Handle

610 4-20 mA current output

210 Rack mounts

730 RS-232 Interface

340 Internal Ozonator

780 RS-485 Interface

350 Internal Ozonator with Remote I/O Activation

[Federal Register: Vol 45, page 57168, 08/27/80]

CARBON MONOXIDE

Advanced Pollution Instrumentation, Inc. Model 300 CO Analyzer

Automated Reference Method: RFCA-1093-093

"Advanced Pollution Instrumentation, Inc. Model 300 Gas Filter Correlation Carbon Monoxide Analyzer," operated on any full scale range between 0-10 ppm and 0-50 ppm, at any temperature in the range of 15°C to 35°C, with the dynamic zero and span adjustment set to *Off*, with a 5-micron TFE filter element installed in the filter assembly, and with or without any of the following options: ² Internal Zero/Span (IZS); Rack Mount With Slides; Zero/Span Valves; RS-232 With Status Outputs.

[Federal Register: Vol. 58, page 58166, 10/29/93]

Beckman Model 866 CO Monitoring System

Automated Reference Method: RFCA-0876-012

"Beckman Model 866 Ambient CO Monitoring System," consisting of the following components: Pump/Sample-Handling Module; Gas Control Panel; Model 865-17 Analyzer Unit; Automatic Zero/Span Standardizer; operated with a 0-50 ppm range, a 13 second electronic response time, with or without any of the following options: Current Output Feature; Bench Mounting Kit; Linearizer Circuit. [Federal Register: Vol. 41, page 36245, 08/27/76]

Bendix/Combustion Engineering Model 8501-5CA CO Analyzer

Automated Reference Method: RFCA-0276-008

"Bendix or Combustion Engineering Model 8501-5CA Infrared CO Analyzer", operated on the 0-50 ppm range and with a time constant setting between 5 and 16 seconds, with or without any of the following options: Rack Mounting With Chassis Slides; Rack Mounting Without Chassis Slides; External Sample Pump. [Federal Register: Vol. 41, page 7450, 02/18/76]

Dasibi Model 3003 CO Analyzer

Automated Reference Method: RFCA-0381-051

"Dasibi Model 3003 Gas Filter Correlation Dasibi Environmental CO Analyzer," operated on the 0-50 ppm range, with a sample particulate filter installed on the sample inlet line, with or without any of the following options:

3-001 Rack Mount 3-003 BCD Digital Output 3-007 Zero/Span Module Panel
3-002 Remote Zero And Span 3-004 4-20 Milliamp Output

[Federal Register: Vol. 46, page 20773, 04/07/81]

Dasibi Model 3008 CO Analyzer

Automated Reference Method: RFCA-0488-067

"Dasibi Model 3008 Gas Filter Correlation CO Analyzer," operated on the 0-50 ppm range, with a time constant setting of 60 seconds, a particulate filter installed in the analyzer sample inlet line, with or without use of the auto zero or auto zero/span feature, and with or without any of the following options: N-0056-A RS-232-C Interface; S-0132-A Rack Mounting Slides; Z-0176-S Rack Mounting Brackets. [Federal Register: Vol. 53, page 12073, 04/12/88]

Environnement S.A. Model CO11M CO Analyzer

Automated Reference Method: RFCA-0995-108

"Environnement S.A. Model CO11M Ambient Carbon Monoxide Analyzer," operated on a full scale range of 0 - 50 ppm, at any temperature in the range of 15 °C to 35 °C, with a 5-micron PTFE sample particulate filter, with the following software settings: Automatic response time ON; Minimum response time set to 40 seconds (RT 13); Automatic ZERO-REF cycle programmed every 24 hours; and with or without any of the following options: ² RS232-422 Serial Interface; Internal Printer.

[Federal Register: Vol. 60, page 54684, 10/25]

Horiba Models AQM-10, AQM-11, and AQM12 CO Monitoring Systems

Automated Reference Method: RFCA-1278-033

"Horiba Models AQM-10, AQM-11, and AQM12 Ambient CO Monitoring Systems," operated on the 0-50 ppm range, with a response time setting of 15.5 seconds, with or without any of the following options: AIC-101 Automatic Indication Corrector; VIT-3 Non-Isolated Current Output; ISO-2 And DCS-3 Isolated Current Output. [Federal Register: Vol. 43, page 58429, 12/14/78]

Horiba Model APMA-300E CO Monitoring System

Automated Reference Method: RFCA-1180-048

"Horiba Model APMA-300E Ambient Carbon Monoxide Monitoring System," operated on the 0-20 ppm¹, the 0-50 ppm, or the 0-100 ppm range with a time constant switch setting of No. 5. The monitoring system may be operated at temperatures between 10°C and 40°C. (This method was originally designated as "Horiba Model APMA 300E/300SE Ambient Carbon Monoxide Monitoring System".) [Federal Register: Vol. 45, page 72774, 11/03/80]

Horiba Model APMA-360 CO Monitor

Automated Reference Method: RFCA-0895-106

"Horiba Instruments Incorporated, Model APMA-360 Ambient Carbon Monoxide Monitor," operated on the 0-50 ppm range, with the Line Setting set to "MEASURE", with the Analog Output set to "MOMENTARY VALUE", and with or without the following options:² 1) Rack Mounting Plate and Side Rails 2) RS-232 Com Port.

[Federal Register: Vol. 60, page 39382, 08/02/95]

MASS-CO, Model 1 CO Analyzer

Automated Reference Method: RFCA-1280-050

"MASS-CO, Model 1 Carbon Monoxide Analyzer," operated on a range of 0-50 ppm, with automatic zero and span adjustments at time intervals not to exceed 4 hours, with or without the 100 millivolt and 5 volt output options. The method consists of the following components: (1) Infra-2 (Uras 2) Infrared Analyzer Model 5611-200-35, (2) Automatic Calibrator Model 5869-111, (3) Electric Gas Cooler Model 7865-222 or equivalent with prehumidifier, (4) Diaphragm Pump Model 5861-214 or equivalent, (5) Membrane Filter Model 5862-111 or equivalent, (6) Flow Meter Model SK 1171-U or equivalent, (7) Recorder Model Mini Comp DN 1/192 or equivalent. NOTE: This method is not now commercially available.

[Federal Register: Vol. 45, page 81650, 12/11/80]

Monitor Labs Model 8310 CO AnalyzerAutomated Reference Method: **RFCA-0979-041**

"Monitor Labs Model 8310 CO Analyzer," operated on the 0-50 ppm range, with a sample inlet filter, with or without any of the following options:

| | | |
|----------------------|------------------|----------------------------------|
| 02A Zero/Span Valves | 04B Pump (50 Hz) | 07A Zero/Span Valve Power Supply |
| 03A Floor Stand | 05A CO Regulator | 08A Calibration Valves |
| 04A Pump (60 Hz) | 06A CO Cylinder | 9A,B,C,D Input Power Transformer |

[Federal Register: Vol. 44, page 54545, 09/20/79 and Vol. 45, page 2700, 01/14/80]

Monitor Labs/Lear Siegler Model 8830 CO AnalyzerAutomated Reference Method: **RFCA-0388-066**

"Monitor Labs or Lear Siegler Model 8830 CO Analyzer," operated on the 0-50 ppm range, with a five micron Teflon filter element installed in the rear-panel filter assembly, with or without any of the following options: 2 - Zero/Span Valve Assembly; 3 - Rack Assembly; 4 - Slide Assembly; 7 - 230 VAC, 50/60 Hz.

[Federal Register: Vol. 53, page 7233, 03/07/88]

Monitor Labs/Lear Siegler Model ML9830,Automated Reference Method: **RFCA-0992-088****Monitor Labs Model ML9830B, or Wedding & Associates Model 1020 CO Analyzers**

"Lear Siegler Measurement Controls Corporation or Monitor Labs Model ML9830, Monitor Labs Model ML9830B, or Wedding & Associates, Inc. Model 1020 Carbon Monoxide Analyzer," operated on any full scale range between 0-5.0 ppm¹ and 0-100 ppm, at any temperature in the range of 15°C to 35°C, with the service switch on the secondary panel set to the *In* position, with the following menu choices selected: Range: 5.0 ppm to 100.0 ppm; Over-ranging: *Enabled or Disabled*; Background: Not Disabled; Calibration: *Manual or Timed*; Diagnostic Mode: *Operate*; Filter Type: *Kalman*; Pres/Temp/Flow Comp: *On*; Span Comp: *Disabled*; and as follows: **Model ML9830:** with a five-micron Teflon® filter element installed internally, with the 50-pin I/O board installed on the rear panel configured at any of the following output range settings: Voltage, 0.1 V, 1 V, 5 V, 10 V; Current, 0-20 mA, 2-20 mA and 4-20 mA; and with or without any of the following options: Valve Assembly for External Zero/Span (EVS); Valve Assembly for Internal Zero/Span (IZS); Rack Mount Assembly; Internal Floppy Disk Drive. **Models ML9830B and 1020:** with either a vendor-supplied or equivalent user-supplied five micron Teflon® filter and exhaust pump, and with or without any of the following options: Valve Assembly for External Zero/Span (EVS); 50-pin I/O board; Rack Mount Assembly; High Pressure Span Valve; hinged, fold-down front panel.

[Federal Register: Vol. 57, page 44565, 09/28/92]

MSA/LIRA Model 202S CO Analyzer SystemAutomated Reference Method: **RFCA-0177-018**

"LIRA Model 202S Air Quality Carbon Monoxide Analyzer System," consisting of a LIRA Model 202S optical bench (P/N 459839), a regenerative dryer (P/N 464084), and rack-mounted sampling system; operated on a 0-50 ppm range, with the slow response amplifier, with or without any of the following options: Remote Meter; Remote Zero And Span Controls; 0-1, 5, 20, Or 50 mA Output; 1-5, 4-20, Or 10-50 mA Output; 0-10 Or 100 mV Output; 0-1, 5, Or 10 Volt Output.

[Federal Register: Vol. 42, page 5748, 01/31/77]

Thermo Electron/Thermo Environmental Instruments Models 48, 48CAutomated Reference Method: **RFCA-0981-054**

"Thermo Electron or Thermo Environmental Instruments, Inc. Model 48 Gas Filter Correlation Ambient CO Analyzer," operated on the 0-50 ppm range, with a time constant setting of 30 seconds, with or without any of the following options:

| | |
|---|--|
| 48-001 Teflon Particulate Filter | 48-010 Internal Zero Air Package |
| 48-002 19 Inch Rack Mount | 48-488 GPIB (General Purpose Interface Bus) EEEE-488 |
| 48-003 Internal Zero/Span Valves with Remote Activation | |

"Thermo Electron or Thermo Environmental Instruments, Inc. Model 48C Gas Filter Correlation Ambient CO Analyzer," operated on any measurement range between 0-1 ppm¹ and 0-100 ppm, with any time average setting from 10 to 300 seconds, with temperature and/or pressure compensation on or off, operated at temperatures between 20°C and 30°C, with or without any of the following

| | | |
|-----------------------|--|--------------------------------|
| options: ² | 100 Teflon particulate filter | 410 Internal Zero Air Scrubber |
| | 200 Carrying Handle | 610 4-20 mA current output |
| | 210 Rack mounts | 720 RS-232 Interface |
| | 320 Internal Zero/Span and Sample/Calibration Solenoid Valves | 770 RS-485 Interface |
| | 330 Internal Zero/Span and Sample/Calibration Solenoid Valves with Remote I/O Activation | |

[Federal Register: Vol. 46, page 47002, 09/23/81]

NITROGEN DIOXIDE

Sodium Arsenite Method for NO₂Manual Equivalent Method: **EQN-1277-026**

"Sodium Arsenite Method for the Determination of Nitrogen Dioxide in the Atmosphere"

[Federal Register: Vol. 42, page 62971, 12/14/77]

Sodium Arsenite Method for NO₂ - Technicon IIManual Equivalent Method: **EQN-1277-027**

"Sodium Arsenite Method for the Determination of Nitrogen Dioxide in the Atmosphere-Technicon II Automated Analyzer System"

[Federal Register: Vol. 42, page 62971, 12/14/77]

TGS-ANSA Method for NO₂Manual Equivalent Method: **EQN-1277-028**

"TGS-ANSA Method for the Determination of Nitrogen Dioxide in the Atmosphere"

[Federal Register: Vol. 42, page 62971, 12/14/77]

Advanced Pollution Instrumentation, Inc. Model 200 NO₂ AnalyzerAutomated Reference Method: **RFNA-0691-082**

"Advanced Pollution Instrumentation, Inc. Model 200 Nitrogen Oxides Analyzer," operated on a range of either 0-0.5 or 0-1.0 ppm, with a 5-micron TFE filter element installed in the rear-panel filter assembly, with either a user- or vendor-supplied vacuum pump capable of providing 5 inches mercury absolute pressure at 5 slpm, with either a user- or vendor-supplied dry air source capable of providing air at a dew point of 0°C or lower, with the following settings of the adjustable setup variables:

| | | |
|-------------------------|-------------------------------------|---------------------------------|
| Adaptive Filter = On | PMT Temperature Set Point = 15°C | Normal Filter Size = 12 samples |
| Dwell Time = 7 seconds | Rate of Change(ROC) Threshold = 10% | Dynamic Span = Off |
| Sample Time = 8 seconds | Reaction Cell Temperature = 50°C | Dynamic Zero = Off |

and with or without any of the following options:

| | | |
|----------------------------|--|-----------------------------|
| 180 Stainless Steel Valves | 283 Internal Zero/Span With Valves (IZS) | 356 Level One Spares Kit |
| 184 Pump Pack | 325 RS-232/Status Output | 357 Level Two Spares Kit |
| 280 Rack Mount With Slides | 355 Expendables | PE5 Permeation Tube for IZS |

[Federal Register: Vol. 56, page 27014, 06/12/91]

Advanced Pollution Instrumentation, Inc. Models 200A/200AU NO₂ AnalyzersAutomated Reference Method: **RFNA-1194-099**

"Advanced Pollution Instrumentation, Inc. Models 200A and 200AU Nitrogen Oxides Analyzers," operated on any full scale range between 0-0.05 ppm and 0-1.0 ppm, with either a 1 or 5-micron TFE filter element installed in the filter assembly, with the following software settings: Dynamic Zero: OFF or ON; Dynamic Span: OFF; Cal-on-NO₂: OFF; Dilution Factor: 1.0; AutoCal: ON or OFF; Independent Range: ON or OFF; AutoRange: ON or OFF; Temp/Pres Compensation: ON; and with or without any of the following options: Rack Mount with Slides, Rack Mount without Slides, Ears Only, Rack Mount for External Pump with Slide Tray, Stainless Steel Zero/Span Valves, 4-20 mA Isolated Outputs, Digital Status Outputs, or RS-232 Outputs. **Model 200A only:** operated at any temperature in the range of 5 °C to 40 °C, with either a user- or vendor-supplied vacuum pump capable of providing an absolute pressure no greater than 10 inches mercury at 1 slpm. Software setting Cal-on-NO₂: OFF, with or without optional Internal Zero/Span with Valves (IZS) and Permeation Tubes for IZS. **Model 200AU only:** operated at any temperature in the range of 20 °C to 30 °C, with either a user- or vendor-supplied vacuum pump capable of providing an absolute pressure no greater than 4 inches mercury at 1 slpm.

[Federal Register: Vol. 59,

page 61892, 12/02/94]

Beckman Model 952-A NO/NO₂/NO_x AnalyzerAutomated Reference Method: **RFNA-0179-034**

"Beckman Model 952-A NO/NO₂/NO_x Analyzer," operated on the 0-0.5 ppm range with the 5-micron Teflon sample filter (Beckman P/N 861072 supplied with the analyzer) installed on the sample inlet line, with or without the Remote Operation Option (Beckman No. 635539).

[Federal Register: Vol. 44, page 7806, 02/07/79]

Bendix Model 8101-B Oxides of Nitrogen AnalyzerAutomated Reference Method: **RFNA-0479-038**

"Bendix Model 8101-B Oxides of Nitrogen Analyzer," operated on a 0-0.5 ppm range with a Teflon sample filter installed on the sample inlet line and with the following post-manufacture modifications: 1) Ozon generator and reaction chamber input-output tubing modification per Bendix Service Bulletin 8101B-2; 2) The approved converter material; 3) The revised and EPA-approved operation and service manual. These items are mandatory and must be obtained from ABB Process Analytics. The analyzer may be operated with or without any of the following optional modifications: a. Perma Pure dryer/ambient air modification; b. Valve cycle time modification; c. Zero potentiometer centering modification per Bendix Service Bulletin 8101B-1; d. Reaction chamber vacuum gauge modification.

[Federal Register: Vol. 44, page 26792, 05/07/79]

Bendix/Combustion Engineering Model 8101-C Oxides of Nitrogen AnalyzerAutomated Reference Method: **RFNA-0777-022**

"Bendix or Combustion Engineering Model 8101-C Oxides of Nitrogen Analyzer", operated on a 0-0.5 ppm range with a Teflon sample filter (Bendix P/N 007163) installed on the sample inlet line.

[Federal Register: Vol. 42, page 37435, 07/2]

Columbia Scientific Industries Models 1600 and 5600 AnalyzersAutomated Reference Method: **RFNA-0977-025**

"CSI Model 1600 Oxides of Nitrogen Analyzer," operated on a 0-0.5 ppm range with a Teflon sample filter (CSI P/N M951-8023) installed on the sample inlet line, with or without any of the following options:

| | |
|--|---|
| 951-0103 Rack Ears | 951-0114 Recorder Output, 5 V |
| 951-0104 Rack Mounting Kit (Ears & Slides) | 951-0115 External Pump (115 V, 60 Hz) |
| 951-0106 Current Output, 4-20 mA (Non-Insulated) | 951-8072 Molybdenum Converter Assembly (Horizontal) |
| 951-0108 Diagnostic Output Option | 951-8074 Copper Converter Assembly (Horizontal) |
| 951-0111 Recorder Output, 10 V | 951-8079 Copper Converter Assembly (Vertical) |
| 951-0112 Remote Zero/Span Sample Control | 951-8085 Molybdenum Converter Assembly (Vertical) |

NOTE: The vertical molybdenum converter assembly is standard on all new analyzers as of 1-1-87; however, use of any of the other converter assemblies is optional. Also, the above options reflect new CSI part numbers.

"CSI Model 5600 Oxides of Nitrogen Analyzer," operated on a 0-0.5 ppm range, with any signal integration time in the range of 20 to 99 seconds, with a Teflon sample filter (CSI P/N M951-8023) installed on the sample inlet line, and with or without any of the following options:

| | | |
|----------------------------------|--------------------------|--|
| 954-0121 Status Contacts | 964-0126 Printer | 954-0131 Rack Mounting Kit (ears and slides) |
| 954-0122 Input Solenoids | 954-8024 Cartridge Dryer | 964-0012 Single Headed Pump - Gast |
| 954-0125 Current Output, 4-20 mA | | 951-0115 Single Headed Pump - KNF |

[Federal Register: Vol. 42, page 46574, 09/16/77]

Dasibi Model 2108 Oxides of Nitrogen AnalyzerAutomated Reference Method: **RFNA-1192-089**

"Dasibi Model 2108 Oxides of Nitrogen Analyzer," operated on the 0-500 ppb range, with software revision 3.6 installed in the analyzer, with the auto thumbwheel switch and the diag thumbwheel switch settings at 0, with the following internal CPU dipswitch settings:

| switch | position | function |
|--------|-------------|---|
| 1 | open (down) | Recorder outputs are NO & NO ₂ |
| 5 | open (down) | 3 minute time constant |
| 6 | closed (up) | 3 minute time constant; |

with a 5-micron Teflon filter element installed in the filter holder, and with or without any of the following options:

| | | |
|--------------------------|----------------|-------------------------------|
| Built-in Permeation Oven | Rack Mounting | Three-Channel Recorder Output |
| RS-232 Interface | 4-20 mA Output | |

[Federal Register: Vol. 57, page 55530, 11/25/92]

DKK Corporation Model GLN-114E Nitrogen Oxides AnalyzerAutomated Reference Method: **RFNA-0798-121**

"DKK Corporation Model GLN-114E Nitrogen Oxides Analyzer," operated within a temperature range of 20 to 30 degrees C on any of the following measurement ranges: 0-0.050, 0-0.100, 0-0.200, 0-0.500, and 0-1.000 ppm

[Federal Register: Vol. 63, page 41253, 08/03/98]

Environnement S. A. Model AC31M NO AnalyzerAutomated Reference Method: **RFNA-0795-104**

"Environnement S. A. Model AC31M Chemiluminescent Nitrogen Oxide Analyzer," operated with a full scale range of 0 - 500 ppb, at any temperature in the range of 15°C to 35°C, with a 5-micron PTFE sample particulate filter, with the following software settings: Automatic response time ON; Minimum response time set to 60 seconds (RT ÷ 2); and with or without any of the following options:² Internal Permeation Oven; Connection for Silica Gel Dryer; RS232-422 interface; EV3 valve; Internal Printer.

[Federal Register: Vol. 60, page 38326, 07/26/95]

Horiba Instruments Model APNA-360 NO-NO₂-NO_x MonitorAutomated Reference Method: **RFNA-0196-111**

"Horiba Instruments, Inc. Model APNA-360 Ambient NO-NO₂-NO_x Monitor," operated with a full scale range of 0 - 0.50 or 0 - 1.0 ppm, at any temperature in the range of 10 °C to 40 °C, with a Line Setting of "MEASURE", and an Analog Output of "MOMENTARY VALUE", and with or without the following options:² 1) Rack Mounting Plate and Side Rails 2) RS-232 Communications Port

[Federal Register: Vol. 61, page 11404, 03/20/96]

Meloy Model NA530R Nitrogen Oxides AnalyzerAutomated Reference Method: **RFNA-1078-031**

"Meloy Model NA530R Nitrogen Oxides Analyzer," operated on the following ranges and time constant switch positions:

| | | | | |
|------------------------|--------------------|---------------------|-----------|-----------|
| Range, ppm: | 0-0.1 ¹ | 0-0.25 ¹ | 0-0.5 | 0-1.0 |
| Time Constant Setting: | 4 | 3 or 4 | 2.3, or 4 | 2.3, or 4 |

Operation of the analyzer requires an external vacuum pump, either Meloy Option N-10 or an equivalent pump capable of maintaining a vacuum of 200 torr (22 inches mercury vacuum) or better at the pump connection at the specified sample and ozone-air flow rates of 1200 and 200 cm³/min, respectively. The analyzer may be operated at temperatures between 10°C and 40°C and at line voltages between 105 and 130 volts, with or without any of the following options: N-1A Automatic Zero And Span; N-2 Vacuum Gauge; N-4 Digital Panel Meter; N-6 Remote Control For Zero And Span; N-6B Remote Zero/Span Control And Status

(Pulse); N-6C Remote Zero/Span Control And Status (Timer); N-9 Manual Zero/Span; N-10 Vacuum Pump Assembly (See Alternate Requirement Above); N-11 Auto Ranging; N-14B Line Transmitter; N-18 Rack Mount Conversion; N-18A Rack Mount Conversion [Federal Register: Vol. 43, page 50733, 10/31/78 and Vol. 44, page 8327, 02/09/79]

Monitor Labs Model 8440E Nitrogen Oxides Analyzer

Automated Reference Method: **RFNA-0677-021**

"Monitor Labs Model 8440E Nitrogen Oxides Analyzer," operated on a 0-0.5 ppm range (position 2 of range switch) with a time constant setting of 20 seconds, with or without any of the following options:

TF- Sample Particulate Filter DO- Status Outputs O18A- Ozone Dry Air O18B- Ozone Dry Air - No Drierite
With TFE Filter Element R- Rack Mount V- Zero/Span Valves FM- Flow meters

[Federal Register: Vol. 42, page 37434, 07/21/77; Vol. 42, page 46575, 09/16/77; Vol. 46, page 29986, 06/04/81]

Monitor Labs/Lear Siegler Model 8840 Nitrogen Oxides Analyzer

Automated Reference Method: **RFNA-0280-042**

"Monitor Labs or Lear Siegler Model 8840 Nitrogen Oxides Analyzer," operated on a range of either 0-0.5 or 0-1.0 ppm, with an internal time constant setting of 60 seconds, a TFE sample filter installed on the sample inlet line, with or without any of the following options:

| | | |
|---|--|----------------------------------|
| 02 Flowmeter | 08A Pump Pac Assembly With 09A (115 VAC) | 011A Recorder Output 1 Volt |
| 03A Rack Ears | 08B Pump Pac Assembly With 09B (100 VAC) | 011B Recorder Output 100 mV |
| 03B Slides | 08C Pump Pac Assembly With 09C (220/240 VAC) | 011C Recorder Output 10 mV |
| 05A Zero/Span Valves | 08D Rack Mount Panel Assembly | 012A DAS Output 1 Volt |
| 05B Valve/Relay | 09A Pump 115 VAC 50/60 Hz | 012B DAS Output 100 mV |
| 06 Status | 09B Pump 100 VAC 50/60 Hz | 012C DAS Output 10 mV |
| 07A Input Power Transformer 100 VAC, 50/60 Hz | 09C Pump 220/240 VAC 50 Hz | 013A Ozone Dry Air |
| 07B Input Power Transformer 220/240 VAC 50 Hz | | 013B Ozone Dry Air - No Drierite |

[Federal Register: Vol. 45, page 9100, 02/11/80 and Vol. 46, page 29986, 06/04/81]

Monitor Labs/Lear Siegler Model 8841 Nitrogen Oxides Analyzer

Automated Reference Method: **RFNA-0991-000**

"Monitor Labs or Lear Siegler Model 8841 Nitrogen Oxides Analyzer," operated on the 0-0.05 ppm¹, 0-0.1 ppm¹, 0-0.2 ppm¹, 0 - 0.5 ppm, or 0-1.0 ppm range, with manufacturer-supplied vacuum pump or alternative user-supplied vacuum pump capable of providing 200 torr or better absolute vacuum while operating with the analyzer. [Federal Register: Vol. 56, page 47473, 9/19/91]

Monitor Labs/Lear Siegler Models ML9841 or ML9841A,

Automated Reference Method: **RFNA-1292-090**

Monitor Labs Model ML9841B, or Wedding & Associates Model 1030 NO₂ Analyzers

"Lear Siegler Measurement Controls Corporation or Monitor Labs Models ML9841 or ML9841A, Monitor Labs Model ML9841B, or Wedding & Associates, Inc. Model 1030 Nitrogen Oxides Analyzers," operated on any full scale range between 0-0.05 ppm¹ and 0-1.0 ppm, at any temperature in the range of 15°C to 35°C, with the service switch on the secondary panel set to the *In* position; with the following menu choices selected: Range: 0.05 ppm to 1.0 ppm; Over-ranging: *Enabled* or *Disabled*; Calibration: *Manual* or *Timed*; Diagnostic Mode: *Operate*; Filter Type: *Kalman*; Pres/Temp/Flow Comp: *On*; Span Comp: *Disabled*; and as follows: **Models ML9841 and ML9841A** - with a five-micron Teflon® filter element installed internally, with the 50-pin I/O board installed on the rear panel configured at any of the following output range setting: Voltage, 0.1 V, 1 V, 5 V, 10 V; Current, 0-20 mA, 2-20 mA, 4-20 mA; and with or without any of the following options: Valve Assembly for External Zero/Span (EVS); Internal Zero/Span (IZS) Assembly for; Rack Mount Assembly; Internal Floppy Disk Drive. **Models ML9841B and 1030** - with a vendor-supplied or equivalent user-supplied five-micron Teflon® filter and exhaust pump, and with or without any of the following options: Valve Assembly for External Zero/Span (EVS); 50-pin I/O board; Internal Zero/Span (IZS) Assembly; Rack Mount Assembly; Charcoal exhaust scrubber; hinged, fold-down front panel. [Federal Register: Vol. 57, page 60198, 12/18/92]

Opsis Model AR 500 and System 300 Open Path Ambient Air Monitoring Systems for NO₂

Automated Equivalent Method: **EQNA-0495-102**

"Opsis Model AR 500 System" or "System 300" Open Path (long path) Ambient Air Monitoring Systems, configured for measuring NO₂, with one detector and movable grating, operated with a measurement range of 0 to 0.5 ppm, an installed monitoring path length between 50 and 500 meters (or 50 and 1000 meters with the ER 150 option, AR 500 System only), xenon lamp type B (150 watt), fiber optic cable length between 3 and 20 meters; operating within an ambient air temperature range of -50 to +50°C, an analyzer temperature range of 20 to 30°C, a measurement (integrating) time setting between 30 and 120 seconds (0 min:30 sec. to 2 min: sec.), and with a complete cycle time of not more than 200 seconds (3 min, 20 sec.). Under this method designation, the Model AR 500 System or System 300 consists of: AR 500 opto-analyser; emitter EM 110 and receiver RE 110 (together identified as ER 110); optic fibre cable OF60-S; power supply PS 150; OPSIS operational software, version 7.0 or 7.1; and initial on-site installation, setup, and limited operator training.²

Optional components that can be used with the Model AR 500 only, in addition to or as alternative to corresponding components listed above:

AR 503 opto-analyzer configured as Model AR 500 (only the center detector active, sequential monitoring)
 Emitter/receiver ER 150 (for monitoring path lengths up to 1 kilometer)
 Transceiver ER 130 and Retroreflector RE 090 with:
 7 prisms (max. monitoring path length 150 meters) or
 12 prisms (max. monitoring path length 250 meters)
 Receiver RE 130
 Xenon lamp type A (higher short-wavelength UV output)
 Optic fibre cable OF60-R (low-loss for short wavelengths)
 Multiplexers MX 004 and MX 024
 Dataloggers DL 010 and DL 016
 Analogue and digital input/output cards AO 008, AI 016, and DI 032
 Analogue and digital isolation cards IA 008, ID 008, OA 008, and OD 008.
 Window heaters HF 110 and HF 150
 Mirror heaters HM 110 and HM 150

Auto calibration unit CU 007
 Software packages IO 80 (for the analogue and digital input/output adapters), DL10 and DL16 (for data loggers), ComVision, and STAT 500;

Recommended calibration and accuracy audit components (or equivalent) for either Model AR 500 or System 300:

Wavelength calibration lamp CA 004
 Calibration bench CB 100
 Receiver unit RE 060 (two required)
 Calibration unit CA 150, with same type lamp as used in the monitoring path emitter
 Power supply PS 150 for calibration unit CA 150
 Calibration cells CC 001-X, where X represents various cell lengths from 1 to 900 mm
 Filter GG 400
 Special calibration cells CC 110 or CC 150 (for mounting directly on receiver)
 Light meter LM 010.

[Federal Register: Vol. 60, page 21518, 05/02/95]

Philips Model PW9762/02 NO/NO₂/NO_x Analyzer

Automated Reference Method: RFNA-0879-040

"Philips Model PW9762/02 NO/NO₂/NO_x Analyzer," consisting of the following components: PW9762/02 Basic Analyzer; PW9729/00 Converter Cartridge; PW9731/00 Sampler or PW9731/20 Dust Filter; operated on a range of 0-0.5 ppm, with or without any of the following accessories: PW9752/00 Air Sampler Manifold; PW9732/00 Sample Line Heater; PW9011/00 Remote Control Set.

[Federal Register: Vol. 44, page 51683, 09/04/79]

Thermo Electron/Thermo Environmental Instruments Model 14 B/E

Automated Reference Method: RFNA-0179-035

"Thermo Electron or Thermo Environmental Instruments, Inc. Model 14 B/E Chemiluminescent NO/NO₂/NO_x Analyzer," operated on the 0-0.5 ppm range, with or without any of the following options:

| | | |
|----------------------------------|--|-------------------------|
| 14-001 Teflon Particulate Filter | 14-003 Long-Time Signal Integrator | 14-005 Sample Flowmeter |
| 14-002 Voltage Divider Card | 14-004 Indicating Temperature Controller | 14-006 Air Filter |

[Federal Register: Vol. 44, page 7805, 02/07/79 and Vol.44, page 54545, 09/20/79]

Thermo Electron/Thermo Environmental Instruments Model 14 D/E

Automated Reference Method: RFNA-0279-037

"Thermo Electron or Thermo Environmental Instruments, Inc. Model 14 D/E Chemiluminescent NO/NO₂/NO_x Analyzer," operated on the 0-0.5 ppm range, with or without any of the following options: 14-001 Teflon Particulate Filter; 14-002 Voltage Divider Card.

[Federal Register: Vol. 44, page 10429, 02/20/79]

Thermo Environmental Instruments Models 42, 42C NO/NO₂/NO_x Analyzer

Automated Reference Method: RFNA-1289-074

"Thermo Environmental Instruments Inc. Model 42 or Model 42C NO-NO₂-NO_x Analyzer," operated on any measurement range between 0-50 ppb¹ and 0-1000 ppb, with any time average setting from 10 to 300 seconds, with temperature and/or pressure compensation on or off, operated at temperatures between 15 °C and 35 °C, with or without any of the following options:²

| | |
|--|--|
| 42-002 Rack mounts | 42-006 Pressure transducer (Model 42 only) |
| 42-003 Internal Zero/span and sample valves with remote activation | 42-007 Ozone particulate filter |
| 42-004 Sample/ozone flow meters (Model 42 only) | 42-008 RS-232/485 interface |
| 42-005 4-20 mA current output | 42-009 Permeation dryer |

[Federal Register: Vol. 54, page 50820, 12/11/89]

LEAD

Reference Method for Lead

Manual Reference Method: 40 CFR Part 50, Appendix G

Reference Method for the Determination of Lead in Suspended Particulate Matter Collected from Ambient Air.

[Federal Register: Vol. 43, page 46258, 10/05/78]

LEAD

List of Designated Reference and Equivalent Methods, September 1, 1999, page 19

Energy-Dispersive X-Ray Fluorescence Spectrometry (TNRCC)

Manual Equivalent Method: **EQL-0783-058**

"Determination of Lead Concentration in Ambient Particulate Matter by Energy-Dispersive X-Ray Fluorescence Spectrometry (Texas Natural Resource Conservation Commission)" Texas Natural Resource Conservation Commission, P.O. Box 13087, Austin, TX 78711-3087.
[Federal Register: Vol. 48, page 29742, 06/28/83]

Energy-Dispersive X-Ray Fluorescence Spectrometry (NEA, Inc.)

Manual Equivalent Method: **EQL-0589-072**

"Determination of Lead Concentration in Ambient Particulate Matter by Energy-Dispersive X-Ray Fluorescence Spectrometry (NEA, Inc.)" Nuclear Environmental Analysis, Inc., Suite 260, 10950 SW 5th Street, Beaverton, OR 97005.
[Federal Register: Vol. 54, page 20193, 05/10/89]

Flame Atomic Absorption Spectrometry

Manual Equivalent Method: **EQL-0380-043**

"Determination of Lead Concentration in Ambient Particulate Matter by Flame Atomic Absorption Spectrometry Following Ultrasonic Extraction with Heated HNO₃-HCl"
Federal Register: Vol. 45, page 14648, 03/06/80]

Flameless Atomic Absorption Spectrometry (EPA/RTP, N.C.)

Manual Equivalent Method: **EQL-0380-044**

"Determination of Lead Concentration in Ambient Particulate Matter by Flameless Atomic Absorption Spectrometry (EPA/RTP, N.C.)"
[Federal Register: Vol. 45, page 14648, 03/06/80]

Flameless (Graphite Furnace) Atomic Absorption (Houston, Texas)

Manual Equivalent Method: **EQL-0895-107**

"Determination of Lead Concentration in Ambient Particulate Matter by Flameless (Graphite Furnace) Atomic Absorption (City of Houston, Texas)." Health and Human Services Department, Environmental Chemistry Service, 1115 S. Braeswood, Houston, TX 77030.
[Federal Register: Vol. 60, page 39383, 08/02/95]

Flameless Atomic Absorption Spectrometry (Omaha)

Manual Equivalent Method: **EQL-0785-059**

"Determination of Lead Concentration in Ambient Particulate Matter by Flameless Atomic Absorption Spectrometry (Omaha-Douglas County Health Department)" Omaha-Douglas County Health Department, 1819 Farnam Street, Omaha, NE 68183
[Federal Register: Vol. 50, page 37909, 09/18/85]

Inductively Coupled Argon Plasma-Optical Emission Spectrometry (Doe Run)

Manual Equivalent Method: **EQL-0196-113**

"Determination of Lead Concentration in Ambient Particulate Matter by Inductively Coupled Argon Plasma-Optical Emission Spectrometry (Doe Run Co.)" Doe Run Company, Smelting Division, 881 Main Street Herculaneum, MO 63048
[Federal Register: Vol. 61, page 11404, 03/20/96]

Inductively Coupled Argon Plasma-Optical Emission Spectrometry (EPA/RTP)

Manual Equivalent Method: **EQL-0380-045**

"Determination of Lead Concentration in Ambient Particulate Matter by Inductively Coupled Argon Plasma-Optical Emission Spectrometry (EPA/RTP, N.C.)"
[Federal Register: Vol. 45, page 14648, 03/06/80]

Inductively Coupled Argon Plasma-Optical Emission Spectrometry (IL)

Manual Equivalent Method: **EQL-1193-094**

"Determination of Lead Concentration in Ambient Particulate Matter by Inductively Coupled Argon Plasma-Optical Emission Spectrometry (State of Illinois)." State of Illinois, Environmental Protection Agency, Champaign Inorganic Laboratory, 2120 South First Street, Champaign, IL 61820
[Federal Register: Vol. 58, page 61902, 11/23/93]

Inductively Coupled Argon Plasma-Optical Emission Spectrometry (Kansas)

Manual Equivalent Method: **EQL-0592-085**

"Determination of Lead Concentration in Ambient Particulate Matter by Inductively Coupled Argon Plasma-Optical Emission Spectrometry (State of Kansas)" State of Kansas, Department of Health and Environment, Forbes Field, Building 740, Topeka, KS 66620-0001.
[Federal Register: Vol. 57, page 20823, 05/15/92]

Inductively Coupled Argon Plasma-Optical Emission Spectrometry (Montana)

Manual Equivalent Method: **EQL-0483-057**

"Determination of Lead Concentration in Ambient Particulate Matter by Inductively Coupled Argon Plasma-Optical Emission Spectrometry (State of Montana)" State of Montana, Department of Health and Environmental Sciences, Cogswell Building, Helena, MT 59620.
[Federal Register: Vol. 48, page 14748, 04/05/83]

Inductively Coupled Argon Plasma-Optical Emission Spectrometry (NETI)

Manual Equivalent Method: **EQL-1188**

"Determination of Lead Concentration in Ambient Particulate Matter by Inductively Coupled Argon Plasma-Optical Emission Spectrometry (Northern Engineering and Testing, Inc.)" Northern Engineering and Testing, Inc., P.O. Box 30615, Billings, MT 59107.
[Federal Register: Vol. 53, page 44947, 11/07/88]

LEAD

List of Designated Reference and Equivalent Methods, September 1, 1999, page 20

Inductively Coupled Argon Plasma-Optical Emission Spectrometry (NH)

Manual Equivalent Method: EQL-1290-080

"Determination of Lead Concentration in Ambient Particulate Matter by Inductively Coupled Argon Plasma-Optical Emission Spectrometry (State of New Hampshire)" State of New Hampshire, Department of Environmental Services, Laboratory Service Unit, 6 Hazen Drive (P.O. Box 95), Concord, NH 03302-0095. [Federal Register: Vol. 55, page 49119, 11/26/90]

Inductively Coupled Argon Plasma-Optical Emission Spectrometry (PA)

Manual Equivalent Method: EQL-0592-086

"Determination of Lead Concentration in Ambient Particulate Matter by Inductively Coupled Argon Plasma-Optical Emission Spectrometry (Commonwealth of Pennsylvania)" Commonwealth of Pennsylvania, Department of Environmental Resources, P.O. Box 2357, Harrisburg, PA 17105-2357. [Federal Register: Vol. 57, page 20823, 05/15/92]

Inductively Coupled Argon Plasma-Optical Emission Spectrometry (Pima, AZ)

Manual Equivalent Method: EQL-0995-109

"Determination of Lead Concentration in Ambient Particulate Matter by Inductively Coupled Argon Plasma-Optical Emission Spectrometry (Pima County, Arizona)." Pima County, Wastewater Management Department, 201 North Stone Avenue, Tucson, Arizona 85701-1207. [Federal Register: Vol. 60, page 54684, 10/25/95]

Inductively Coupled Argon Plasma-Mass Spectrometry (Pima Co., AZ)

Manual Equivalent Method: EQL-0995-110

"Determination of Lead Concentration in Ambient Particulate Matter by Inductively Coupled Plasma-Mass Spectrometry (Pima County, Arizona)." Pima County, Wastewater Management Department, 201 North Stone Avenue, Tucson, Arizona 85701-1207. [Federal Register: Vol. 60, page 54684, 10/25/95]

Inductively Coupled Argon Plasma-Optical Emission Spectrometry (RI)

Manual Equivalent Method: EQL-0888-068

"Determination of Lead Concentration in Ambient Particulate Matter by Inductively Coupled Argon Plasma-Optical Emission Spectrometry (State of Rhode Island)." State of Rhode Island Department of Health, Air Pollution Laboratory, 50 Orms Street, Providence, RI 02904 [Federal Register: Vol. 53, page 30866, 08/16/88]

Inductively Coupled Argon Plasma-Optical Emission Spectrometry (Silver Valley)

Manual Equivalent Method: EQL-1288-070

"Determination of Lead Concentration in Ambient Particulate Matter by Inductively Coupled Argon Plasma-Optical Emission Spectrometry (Silver Valley Laboratories)" Silver Valley Laboratories, Inc., P.O. Box 929, Kellogg, ID 83837. [Federal Register: Vol. 53, page 48974, 12/05/88]

Inductively Coupled Argon Plasma-Optical Emission Spectrometry (WV)

Manual Equivalent Method: EQL-0694-096

"Determination of Lead Concentration in Ambient Particulate Matter by Inductively Coupled Argon Plasma-Optical Emission Spectrometry (State of West Virginia)." State of West Virginia, Department of Commerce, Labor and Environmental Resources, Division of Environmental Protection, 1558 Washington Street East, Charleston, WV 25311-2599 [Federal Register: Vol. 59, page 29429, 06/07/94]

Wavelength Dispersive X-Ray Fluorescence Spectrometry (CA)

Manual Equivalent Method: EQL-0581-052

"Determination of Lead Concentration in Ambient Particulate Matter by Wavelength Dispersive X-Ray Fluorescence Spectrometry" California Department of Health Services, Air & Industrial Hygiene Laboratory, 2151 Berkeley Way, Berkeley, CA 94704. [Federal Register: Vol. 46, page 29986, 06/04/81]

NOTES

¹ Users should be aware that designation of this analyzer for operation on ranges less than the range specified in the performance specifications for this analyzer (40 CFR 53, Subpart B) is based on meeting the same absolute performance specifications required for the specified range. Thus, designation of these lower ranges does not imply commensurably better performance than that obtained on the specified range.

² This analyzer is approved for use, with proper factory configuration, on either 50 or 60 Hertz line frequency and nominal power line voltages of 115 Vac and 220 Vac.

Sources or Contacts for Designated Reference and Equivalent Methods

ABB Process Analytics
P.O. Box 831
Lewisburg, WV 24901
(304) 647-4358

Advanced Pollution
Instrumentation, Inc.
6565 Nancy Ridge Drive
San Diego, CA 92121-2251
(619) 657-9800

Andersen Instruments
500 Technology Court
Smyrna, GA 30082-9211
(800) 241-6898

ASARCO Incorporated
3422 South 700 West
Salt Lake City, UT 84119
(801) 262-2459

Beckman Instruments, Inc.
Process Instruments Division
2500 Harbor Blvd.
Fullerton, CA 92634
(714) 871-4848

Bendix
[Refer to ABB Process Analytics]

BGI Incorporated
58 Guinan Street
Waltham, MA 02154

Columbia Scientific Industries
11950 Jollyville Road
Austin, TX 78759
(800) 531-5003

Combustion Engineering
[Refer to ABB Process Analytics]

Dasibi Environmental Corp.
506 Paula Avenue
Glendale, CA 91201
(818) 247-7601

DKK Corporation
4-13-14 Kichijoji Kitamachi.
Musashino-shi
Tokyo, 180, Japan

Environnement S.A
111, bd Robespierre
78300 Poissy, France
Instruments also available from:
Altech/Environnement U.S.A.
7206 Impala Drive
Richmond, VA 23228
(804) 262-4447
kchaffee@altechusa.com

Envionics, Inc.
69 Industrial Park Rd. E.
Tolland, CT 06084-2805
(203) 429-0077

Graseby CMW
[Refer to Andersen Instruments]

Horiba Instruments Incorporated
17671 Armstrong Avenue
Irvine, CA 92714
(800) 446-7422

Lear Siegler
[Refer to Monitor Labs, Inc.]

Commonwealth of Massachusetts
Department of Environmental
Quality Engineering
Tewksbury, MA 01876

Met One Instruments, Inc.
1600 Washington Blvd.
Grants Pass, OR 97526

McMillan
[Refer to Columbia Scientific
Industries]

Mine Safety Appliances
600 Penn Center Blvd.
Pittsburgh, PA 15235-5810
(412) 273-5101

Monitor Labs, Inc.
74 Inverness Drive
Englewood, CO 80112-5189
(800) 422-1499

Opsis AB, Furulund, Sweden
Instruments also available from:
Opsis, Inc.
146-148 Sound Beach Avenue
Old Greenwich, CT 06870
(203) 698-1810

State of Oregon
Department of Environmental Quality
Air Quality Division
811 S.W. Sixth Avenue
Portland, OR 97204

PCI Ozone Corp.
One Fairfield Crescent
West Caldwell, NJ 07006
(201) 575-7052

Phillips Electronic Instruments, Inc.
85 McKee Drive
Mahwah, NJ 07430

Rupprecht & Patashnik Co., Inc.
25 Corporate Circle
Albany, NY 12203
(518) 452-0065

Thermo Environmental Instruments,
Inc.
8 West Forge Parkway
Franklin, MA 02038
(508) 520-0430

U.S. EPA
National Exposure Research Laboratory
Human Exposure & Atmospheric
Sciences Division
MD-46
Research Triangle Park, NC 27711
(919) 541-2622

Wedding and Associates, Inc.
[Refer to Thermo Environmental
Instruments, Inc.]

1000 APPENDICES

**Ambient
Air
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APPENDIX C

QA AUDIT - STATION DATA WORKSHEET

QA AUDIT - VAN DATA WORKSHEET

QA AUDIT HIVOL SAMPLER AUDIT WORKSHEET

QA AUDIT WORKSHEET - STATION DATA

Site Name: _____ Site Number: _____ Date: _____
 Address: _____ Site Phone Number: _____
 Data Read From: Chart[] DAS[] Other[] Type: _____
 Correction For Zeroes: YES[] NO[] Booster Pump Flow Rate: _____
 Station Manifold Pressure: Before Audit: _____ During Audit: _____

Instrument Range And Response

| Audit Point | O3 | CO | THC | CH4 | NMHC | SO2 | H2S | Ozone Off | | Ozone On | |
|--------------|----|----|-----|-----|------|-----|-----|-----------|-----|----------|-----|
| | | | | | | | | NO | NOX | NO | NOX |
| Range (PPM) | | | | | | | | | | | |
| Pre-Zero | | | | | | | | | | | |
| High-1st Pt. | | | | | | | | | | | |
| Med-2nd Pt. | | | | | | | | | | | |
| NOX-1st Pt. | | | | | | | | | | | |
| NOX-2nd Pt. | | | | | | | | | | | |
| Low-3rd Pt. | | | | | | | | | | | |
| NOX-Opt Pt. | | | | | | | | | | | |
| Post-Zero | | | | | | | | | | | |

Station Instrument Information

| Instruments | Ozone | CO | THC/CH4/NMHC | SO2/H2S | NO/NOX |
|------------------------|-------|----|-----------------------|---------|--------|
| Manufacturer | | | | | |
| Model Number | | | | | |
| Property Number | | | | | |
| Calibration Date | | | | | |
| EPA Equivalency # | | | | | |
| Monitor Designation | | | | | |
| Zero & Span Settings | | | | | |
| Indicated Flow | | | | | |
| Pressure/Vacuum | | | | | |
| In-Line Filter Changed | | | | | |
| | | | Converter Temperature | | |

Calibration Equipment

| Equipment | Equipment Type | Identification Number | Certification Date |
|-------------------|----------------|-----------------------|--------------------|
| Calibration Gas | | | |
| Hi-Vol Calibrator | | | |
| Gas Calibrator | | | |
| Ozone Calibrator | | | |

QA AUDIT WORKSHEET - VAN DATA

Site Name: _____ Date: _____
 Site Num. _____ TECO 48 I.D. #: _____ API 400 I.D. #: _____
 VAN: A[] B[] C[] Van Flow: _____ Station Flow: _____
 Quarter: 1[] 2[] 3[] 4[] Standards Version _____ Year: _____
 Auditors: _____ / _____

| Van Ozone Responses | | |
|---------------------|---------------|-----------------|
| Audit Point | Ozone Setting | Display Reading |
| 1 | 0 | |
| 2 | 400 | |
| 3 | 175 | |
| 4 | 70 | |
| 5 | 0 | |

Barometric Pressure
_____ Volts

Air Flow Display
_____ lpm

| Van CO Calibration Responses | | | | | | | |
|------------------------------|---------|--------|-----------|--|----------------------|---------|-----------|
| Pre-Audit Responses | | | | | Post-Audit Responses | | |
| API 701 | High CO | Low CO | Ultrapure | | API 701 | High CO | Ultrapure |
| | | | | | | | |

| Van CO Dilution Responses | | | | | | | | |
|---------------------------|------------|--------------|--------|-----|--------|-----|--------------|--------------------|
| Audit Point | Audit Mode | Target Ozone | Target | | Actual | | CO Set Point | CO Display Reading |
| | | | Air | Gas | Air | Gas | | |
| | Zero | | | | | | | |
| | High | | | | | | | |
| | Middle | | | | | | | |
| | NO2 | | | | | | | |
| | Option | | | | | | | |
| | NO2 | | | | | | | |
| | Low | | | | | | | |
| | NO2 | | | | | | | |
| | Opt NO | | | | | | | |
| | Zero | | | | | | | |

QA AUDIT WORKSHEET - PM10 & TSP

Site Name: _____ Site #: _____ Date: _____

Address: _____ Agency: _____

Technician: _____ Auditors: _____ / _____

Model: _____ ID#: _____ SSI[] TSP[] Lead[] NAMS[] SLAMS[] SPM[]

| Calibrator Static Pressure P | | | |
|------------------------------|-------|-------|---------|
| Run 1 | Run 2 | Run 3 | Average |
| | | | |

| Indicated Flow / Stagnation Pressure (Qind) (Pstg) | | | |
|--|-------|-------|---------|
| Run 1 | Run 2 | Run 3 | Average |
| | | | |

| Standard Flow SCFM (Qstd) |
|---------------------------|
| |

Cal. _____ Magnehelic _____ EPA Equiv. _____ Collocated _____ Passed FCT _____
 Date: _____ Reading: _____ Number: _____ Yes[] No[] Yes[] No[]

Slope: _____ Intercept: _____ Barometer: _____ Temperature: _____ °C

Model: _____ ID#: _____ SSI[] TSP[] Lead[] NAMS[] SLAMS[] SPM[]

| Calibrator Static Pressure P | | | |
|------------------------------|-------|-------|---------|
| Run 1 | Run 2 | Run 3 | Average |
| | | | |

| Indicated Flow / Stagnation Pressure (Qind) (Pstg) | | | |
|--|-------|-------|---------|
| Run 1 | Run 2 | Run 3 | Average |
| | | | |

| Standard Flow SCFM (Qstd) |
|---------------------------|
| |

Cal. _____ Magnehelic _____ EPA Equiv. _____ Collocated _____ Passed FCT _____
 Date: _____ Reading: _____ Number: _____ Yes[] No[] Yes[] No[]

Slope: _____ Intercept: _____ Barometer: _____ Temperature: _____ °C

Model: _____ ID#: _____ SSI[] TSP[] Lead[] NAMS[] SLAMS[] SPM[]

| Calibrator Static Pressure P | | | |
|------------------------------|-------|-------|---------|
| Run 1 | Run 2 | Run 3 | Average |
| | | | |

| Indicated Flow / Stagnation Pressure (Qind) (Pstg) | | | |
|--|-------|-------|---------|
| Run 1 | Run 2 | Run 3 | Average |
| | | | |

| Standard Flow SCFM (Qstd) |
|---------------------------|
| |

Cal. _____ Magnehelic _____ EPA Equiv. _____ Collocated _____ Passed FCT _____
 Date: _____ Reading: _____ Number: _____ Yes[] No[] Yes[] No[]

Slope: _____ Intercept: _____ Barometer: _____ Temperature: _____ °C

QA AUDIT PM2.5 SAMPLER WORKSHEET FOR SEQUENTIAL SAMPLERS

Site Name: _____ Site No: _____ AIRS No: _____ Date: _____
 Agency: _____ Site Operator: _____ Quarter: 1[] 2[] 3[] 4[]
 Auditors: _____ / _____ NAMS[] SLAMS[] PAMS[] SPM[]

Sampler Information

| Make | Model | ID Number | Sampling Schedule | Last Cal. Date | Collocated (Y/N) |
|------|-------|-----------|-------------------|----------------|------------------|
| | | | | | |

Audit Equipment Information

| Audit Device | Make/Model | ID Number | Range |
|--------------------|------------|-----------|-------|
| Audit MFM | | | |
| Temperature Sensor | | | |
| Pressure Sensor | | | |

Sampler Calibration Information (Gain and Offset Values)

| Measurement | Gain | Offset |
|-----------------------------|------|--------|
| Ambient Temperature (Amb): | | |
| Filter Temperature (Filtr): | | |
| Barometric Pressure (Baro): | | |
| Flow Rate: | | |

Audit Data Flow Rates

| Flow Point | Sampler Q_a (LPM) | Audit Q_{ind} (Display) |
|------------|---------------------|---------------------------|
| 1 | | |
| 2 | | |
| 3 | | |

Ambient Temp.
 T_a (°C)

Ambient Pressure
 P_a (mmHg/volts)

 (Avg.) _____

 (Avg.) _____

Sampler Temperature Sensor

| Test Point | Sampler Sensor T_{sam} (°C) | Audit Sensor T_a (°C) |
|------------------------|----------------------------------|----------------------------|
| Active Filter Sensor | | |
| Inactive Filter Sensor | | |

Sampler Pressure Sensor

| Sampler Sensor P_{sam} (mmHg) | Audit Sensor P_a (mmHg/volts) |
|------------------------------------|------------------------------------|
| | |

Ambient Temperature Sensor – Water Bath

| Test Point | Sampler Sensor T_{sam} (°C) | Audit Sensor T_a (°C) |
|-------------|----------------------------------|----------------------------|
| 1 (Cold) | | |
| 2 (Ambient) | | |
| 3 (Hot) | | |

Temperature Sensors – Collocated

| Test Point | Sampler Sensor T_{sam} (°C) | Audit Sensor T_a (°C) |
|----------------|----------------------------------|----------------------------|
| Ambient Sensor | | |
| DGM Sensor* | | |

*Conduct only with operator present.

QA AUDIT PM2.5 SAMPLER WORKSHEET FOR SINGLE CHANNEL SAMPLERS

Site Name: _____ Site No: _____ AIRS No: _____ Date: _____

Agency: _____ Site Operator: _____ Quarter: 1[] 2[] 3[] 4[]

Auditors: _____ / _____ NAMS[] SLAMS[] PAMS[] SPM[]

Sampler Information

| Make | Model | ID Number | Sampling Schedule | Last Cal. Date | Collocated (Y/N) |
|------|-------|-----------|-------------------|----------------|------------------|
| | | | | | |

Audit Equipment Information

| Audit Device | Make/Model | ID Number | Range |
|--------------------|------------|-----------|-------|
| Audit MFM | | | |
| Temperature Sensor | | | |
| Pressure Sensor | | | |

Sampler Calibration Information (Offset and Span Values)

| Measurement | Offset | Span* |
|-----------------------------|--------|-------|
| Ambient Temperature (Amb): | | |
| Filter Temperature (Filtr): | | |
| Barometric Pressure (Baro): | | |
| Flow Rate: | | |

*Some values may not be present.

START / END TIME: _____ START / END DATE: _____

Audit Data Flow Rates

| Flow Point | Sampler Q _a (LPM) | Audit Q _{ind} (Display) |
|------------|------------------------------|----------------------------------|
| 1 | | |
| 2 | | |
| 3 | | |

Ambient Temp.
T_a (°C)

(Avg.) _____

Ambient Pressure
P_a (mmHg/volts)

(Avg.) _____

Sampler Temperature Sensor

| Test Point | Sampler Sensor T _{sam} (°C) | Audit Sensor T _a (°C) |
|---------------|---|-------------------------------------|
| Active Filter | | |

Sampler Pressure Sensor

| Sampler Sensor P _{sam} (mmHg) | Audit Sensor P _a (mmHg/volts) |
|---|---|
| | |

Ambient Temperature Sensor – Water Bath

| Test Point | Sampler Sensor T _{sam} (°C) | Audit Sensor T _a (°C) |
|-------------|---|-------------------------------------|
| 1 (Cold) | | |
| 2 (Ambient) | | |
| 3 (Hot) | | |

Ambient Temperature Sensor – Collocated

| Test Point | Sampler Sensor T _{sam} (°C) | Audit Sensor T _a (°C) |
|------------|---|-------------------------------------|
| Ambient | | |

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**Ambient
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APPENDIX D

SYSTEM AUDIT WORKSHEETS

A. NETWORK MANAGEMENT

1. General

| Questions | Yes | No | Comments |
|--|-----|----|----------|
| a) Is there an organization chart showing the agency's structure and its reporting organization (attach charts)? | | | |
| b) Basis for the current structure of the agency's reporting organization? | | | |
| Field operations for all local agencies, conducted by a common team of field operators? | | | |
| Common calibration facilities are used for all local agencies? | | | |
| Precision checks performed by common staff for all local agencies? | | | |
| Accuracy checks performed by common staff for all local agencies? | | | |
| Data handling follows uniform procedure for all local agencies? | | | |
| Traceability of all standards by one central support laboratory? | | | |
| One central analytical laboratory handles all analyses for manual methods? | | | |
| c) Does the agency feel that the data for the reporting organizations it contains can be pooled? | | | |

d) Describe any changes which will be made within the agency's monitoring program the next calendar year

| e) Complete the table below for each of the pollutants monitored as part of your air monitoring network | | | | | | | |
|---|-----------------|-----------------|----|----------------|-------|--------|----|
| | SO ₂ | NO ₂ | CO | O ₃ | PM-10 | PM-2.5 | Pb |
| NAMS | | | | | | | |
| SLAMS | | | | | | | |
| SPM | | | | | | | |
| PAMS | | | | | | | |
| Total | | | | | | | |

| Question | Yes | No | Comment |
|---|-----|----|---------|
| f) What is the most current official SLAMS Network Description? | | | |
| I. Is it available for public inspection | | | |
| II Does it include the following for each site | | | |
| Monitor ID Code (AIRS Site ID#) | | | |
| Sampling and Analysis Method | | | |
| Operative Schedule | | | |
| Monitoring Objective and Scale of Representativeness | | | |
| Any Proposed Changes | | | |

| | | | |
|----------------------------------|--------------------|---------------------------|-----------|
| g) Modification since last audit | | Date of last audit: _____ | |
| | Number of Monitors | | |
| Pollutant | Added | Deleted | Relocated |
| SO ₂ | | | |
| NO ₂ | | | |
| CO | | | |
| O ₃ | | | |
| PM-10 | | | |
| PM-2.5 | | | |
| Pb | | | |

H) What changes to the Air Monitoring Network are planned for the next period (discuss equipment needs in section B.3.g)

| Question | Yes | No | Comment |
|---|-----|----|---------|
| I) Does an overall SLAM/NAMS Monitoring Plan exist? | | | |
| j) Has the agency prepared and implemented standard operating procedures (SOPs) for all facets of agency operation? | | | |
| k) Do the SOPs adequately address ANSI/ASQC E-4.quality system required by 40 CFR App A | | | |

l) Clearly identify by section number and /or document title, major changes made to documents since the last on-site review

| Title/Section # | Pollutant(s) Affected |
|-----------------|-----------------------|
| | |
| | |
| | |
| | |

| Question | Yes | No | Comment |
|--|-----|----|---|
| m) Does the agency have an implemented plan for operations during emergency episodes? Indicate latest revision, approval date and current location of this plan | | | Document Title Revision Date: Approved: |
| n) During episodes, are communications sufficient so that regulatory actions are based on real time data? | | | |
| o) Identify the section of the emergency episode plan where quality control procedures can be found. | | | |

2. Network Design and Siting

a) Indicate by Site ID # any non-conformance with the requirements of 40 CFR 58, Appendices D and E

| Monitor | Site ID | Reason for Non-Conformance |
|-----------------|---------|----------------------------|
| SO ₂ | | |
| O ₃ | | |
| CO | | |
| NO ₂ | | |
| PM-10 | | |
| PM-2.5 | | |
| Pb | | |

b) Please provide the following information on your previous Network Review required by 40 CFR 58.20d.

Review performed on: Date

Performed by:

Location and title of review document:

Briefly discuss all problems uncovered by this review

| Question | Yes | No | Comment |
|---|-----|----|------------------------------------|
| c) Have NAMS hard copy information reports been prepared and submitted for all monitoring sites within the network? | | | |
| d) Does each site have the required information including: | | | |
| AIRS Site ID Number? | | | |
| Photographs/slides to the four cardinal compass points? | | | |
| Startup and shutdown dates? | | | |
| Documentation of instrumentation? | | | |
| Reasons for periods of missing data? | | | |
| e) Who has custody of the current network documents | | | Name: Title: |
| f) Does the current level of monitoring effort, site placement, instrumentation, etc., meet requirements imposed by current grant conditions? | | | |
| g) How often is the network design and siting reviewed? | | | Frequency: Date of last review: |

| h) Provide a summary of the monitoring activities conducted as the SLAMS/NAMS network by the agency | | | |
|---|---------------------|--------------------|------------------|
| I. Monitoring is <i>seasonal</i> for (indicate pollutant and month of high and low concentrations). | | | |
| Pollutant | High Concentrations | Low Concentrations | Collocated (Y/N) |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

| II Monitoring is <i>year-round</i> for (indicate pollutant) | |
|---|------------------|
| Pollutant | Collocated (Y/N) |
| | |
| | |
| | |
| | |

| Question | Yes | No | Comment |
|--|-----|----|---------|
| i) Does the number of collocated monitoring sites meet the requirements of 40 CFR 58 Appendix A? | | | |
| j) Does the agency monitor and/or analyze for non-criteria air and /or toxic air pollutants? | | | |

If j is yes complete forms below

| Pollutant | Monitoring Method/Instrument | SOP Available (Y/N) |
|-----------|------------------------------|---------------------|
| | | |
| | | |
| | | |

3. Organization, Staffing and Training

a) Key Individuals

Agency Director:
 Slams Network Manager:
 Quality Assurance Officer:
 Field Operations Supervisor:
 Laboratory Supervisor:
 Data Management Supervisor:
 SLAMS Reporting Supervisor:

| b) Number of personnel available to each of the following program areas | | |
|---|--------|--|
| Program Area | Number | Comment on need for additional personnel |
| Network Design and Siting | | |
| Resources and Facilities | | |
| Data and Data Management | | |
| QA/QC | | |

| Question | Yes | No | Comment |
|---|-----|----|---------|
| c) Does the agency have an established training program? | | | |
| I Where is it documented | | | |
| II Does it make use seminars, courses, EPA sponsored college level courses? | | | |

| III Indicate below the 3 most recent training events and identify the personnel participating in them. | | |
|--|-------|----------------|
| Event | Dates | Participant(s) |
| | | |
| | | |
| | | |

4. Facilities

| a) Identify the principal facilities where the work is performed which is related to the SLAMS/NAMS network. Do not include monitoring sites but do include any work which is performed by contract or other arrangements | | |
|---|----------|--------------------------|
| Facility | Location | Main SLAMS/NAMS Function |
| | | |
| | | |
| | | |

b) Indicate any areas of facilities that should be upgraded. Identify by location

| c) Are there any significant changes which are likely to be implemented to agency facilities before the next systems audit? Comment on your agency's needs for additional physical space (laboratory, office, storage, etc.) | | |
|--|----------|------------------------|
| Facility | Function | Proposed Change - Date |
| | | |
| | | |
| | | |

B: FIELD OPERATIONS

1. Routine Operations

Complete the table

| Pollutant Monitored | Date of Last SOP Revision |
|---------------------|---------------------------|
| SO ₂ | |
| NO ₂ | |
| CO | |
| O ₃ | |
| PM-10 | |
| PM-2.5 | |
| Pb | |

| Question | Yes | No | Comment |
|--|-----|----|---------|
| a) Is the documentation of monitoring SOPs complete | | | |
| b) Are such procedures available to all field operations personnel | | | |
| c) Are SOPs prepared and available to field personnel which detail operations during episode monitoring? | | | |

| d) For what does each reporting organization within the agency monitor | | |
|--|------------|------------|
| Reporting Organization | # of Sites | Pollutants |
| | | |
| | | |
| | | |
| | | |
| | | |

| Question | Yes | No | Comment |
|---|-----|----|-----------------------|
| e) On average, how often are most of your sites visited by a field operator? | | | _____ per _____ |
| f) Is this visit frequency consistent for all reporting organizations within your agency. | | | If no, why: |
| g) On average, how many sites does a single site operator have responsibility for? | | | |
| h) How many of the sites of your SLAMS/NAMS network are equipped with manifolds(s) | | | |
| I Briefly describe most common manifold type | | | |
| II Are Manifolds cleaned periodically | | | How often? |
| III If the manifold is cleaned, what is used | | | |
| IV Are manifold(s) equipped with a blower | | | |
| V Is there sufficient air flow through the manifold at all times? | | | Approximate air flow: |
| VI Is there a conditioning period for the manifold after cleaning? | | | Length of time: |
| 1) What material is used for instrument lines? 2) How often are lines changed? | | | |
| j) Has the agency obtained necessary waiver provisions to operate equipment which does not meet the effective reference and equivalency requirements? | | | |

| k) Please complete the table below to indicate which analyzers do not conform with the requirements of 40 CFR 53 for NAMS, SLAMS, or SIP related SPM's | | | | |
|--|--------|------------|---------|-----------------------|
| Pollutant | Number | Make/Model | Site ID | Comments on Variances |
| SO ₂ | | | | |
| NO ₂ | | | | |
| CO | | | | |
| O ₃ | | | | |
| PM-10 | | | | |
| PM-2.5 | | | | |
| Pb | | | | |

l) Please comment briefly and prioritize your currently identified instrument needs

2 Quality Control

| a) Please indicate the frequency of multi point calibrations | | |
|--|-----------|-----------|
| Reporting Organization | Pollutant | Frequency |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

| Question | Yes | No | Comment |
|--|-----|----|----------------------------|
| b) Are field calibration procedures included in the document SOPs | | | Location (site, lab etc.): |
| c) Are calibrations performed in keeping with the guidance in section Vol II of the QA Handbook for Air Pollution Measurement Systems? | | | If no, why? |
| d) Are calibration procedures consistent with the operational; requirements of Appendices to 40 CFR 50 or to analyzer operation/instruction manuals. | | | If no, why? |
| e) Have changes been made to calibration methods based on manufacturer's suggestions for a particular instrument | | | |
| f) Do standard materials used for calibrations meet the requirements of appendices to 40 CFR 50 (EPA reference methods) and Appendix A to 40 CFR (traceability of materials to NIST-SRMs or CRMs)? | | | Comment on deviations |
| g) Are all flow-measurement devices checked and certified ? | | | |

| h) Please list the authoritative standards used for each type of flow measurement, indicate the frequency of calibration standards to maintain field material/device credibility | | |
|--|------------------|--------------------------|
| Flow Device | Primary Standard | Frequency of Calibration |
| | | |
| | | |
| | | |
| | | |
| | | |

| Question | Yes | No | Comment |
|---|-----|----|---------------------|
| i) Where do field operations personnel obtain gaseous standards? | | | |
| Are those standards certified by: | | | |
| The agency laboratory | | | |
| EPA/NERL standards laboratory | | | |
| A laboratory separate from this agency's but part of the same reporting organization? | | | |
| The vendor? | | | |
| NIST | | | |
| j) Does the documentation include expiration data of certification? | | | |
| Reference to primary standard used | | | |
| What traceability is used? | | | |
| Please attach an example of recent documentation of traceability | | | |
| k) Is calibration equipment maintained at each site? | | | For what pollutants |
| l) How is the functional integrity of this equipment documented | | | |

| m) Please complete the table below for your agency's site standards (up to 7% of the sites, not to exceed 20 sites) | | | |
|---|------------------|--------------------|----------------------|
| Parameter | Primary Standard | Secondary Standard | Recertification Date |
| CO | | | |
| NO ₂ | | | |
| SO ₂ | | | |
| O ₃ | | | |

| Please complete the table below for Continuous Analyzers | | |
|--|------------|-----------|
| Pollutant | Span Conc. | Frequency |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

| PM 10 Analyzers | |
|-----------------------------|-----------|
| Flow Rate | Frequency |
| | |
| | |
| | |
| PM _{2.5} Analyzers | |
| | |
| | |
| | |

| Question | Yes | No | Comment |
|---|-----|----|---|
| n) Are level 1 zero and span (z/s) calibrations (or calibration checks made for all continuous monitoring equipment and flow checks made for PM 10 and PM2.5 samplers | | | |
| o) Does the agency have acceptance criteria for zero/span checks | | | |
| I. Are these criteria known to the field operations personnel? | | | |
| II. Are they documented in standard operating procedures? | | | If not indicate document and section where they can be found? |
| III. Do the documents discussed in (II) above indicate when zero/span adjustments should and should not be made? | | | Indicate an example |
| IV. Are zero and span check control charts maintained? | | | |

| Question | Yes | No | Comment |
|---|-----|----|-------------------------------------|
| p) In keeping with 40 CFR 58 regulations, are any necessary zero and span adjustments made after precision checks? | | | If no, why not? |
| (q) Are precision check control charts maintained? | | | |
| (r) Who has the responsibility for performing zero/span checks? | | | |
| (s) Are precision checks routinely performed within concentration ranges and with a frequency which meets or exceeds the requirements of 40 CFR 58, Appendix A? | | | Please comment on any discrepancies |

(t) Please identify person(s) with the responsibility for performance of precision checks on continuous analyzers.

Person(s) _____

Title _____

3. Preventive Maintenance

a) Has the field operator been given any special training in performing preventive maintenance? Briefly comment on background and/or courses

b) Is this training routinely reinforced? Yes ___ No ___
If no, why not?

c) If preventive maintenance is MINOR, it is performed at (check one or more): field site ___, Headquarters facilities ___, equipment is sent to manufacturer _____

d) If preventive maintenance is MAJOR, it is performed at (check one or more): field site ___, Headquarters facilities ___, equipment is sent to manufacturer _____

e) Does the agency have service contracts or agreements in place with instrument manufacturers? Indicate below or attach additional pages to show which instrumentation is covered.

f) Comment briefly on the adequacy and availability of the supply of spare parts, tools and manuals available to the field operator to perform any necessary maintenance activities. Do you feel that this is adequate to prevent any significant data loss?

g) Is the agency currently experiencing any recurring problem with equipment or manufacturer(s)? If so, please identify the equipment and/or manufacturer, and comment on steps taken to remedy the problem.

4. Record Keeping

| Question | Yes | No | Comment |
|---|-----|----|--|
| a) Is a log book(s) maintained at each site to document site visits, preventive maintenance and resolution of site operational problems and corrective actions taken? | | | Other uses? |
| b) Is the logbook maintained currently and reviewed periodically? | | | Frequency of Review |
| (c) Once entries are made and all pages filled, is the logbook sent to the laboratory for archiving? | | | If no, is it stored at other location(s) (specify) |
| (d) What other records are used? | | | |
| Zero/span record? | | | |
| Gas usage log? | | | |
| Maintenance log? | | | |
| Log of precision checks? | | | |
| Control charts? | | | |
| A record of audits? | | | |
| Please describe the use and storage of these documents. | | | |
| | | | |
| (e) Are calibration records or at least calibration constants available to field operators? | | | |
| Please attach an example field calibration record sheet to this questionnaire | | | |

5. Data Acquisition and Handling

(a) With the exception of PM 10, are instrument outputs (that is data) recorded to (a) stripcharts, (b) magnetic tape acquisition system, (c) digitized and telemetered directly to agency headquarters? Please complete the table below for each of the reporting organizations, or agencies within the overall R.O.

| | | |
|-------------------------------|-------------------|--|
| <u>Reporting Organization</u> | <u>Pollutants</u> | <u>Data Acquisition Media (a, b, c or combination)</u> |
|-------------------------------|-------------------|--|

| Question | Yes | No | Comment |
|---|-----|----|---|
| b) Is there stripchart backup for all continuous analyzers? | | | |
| (c) Where is the flow of high-volume samplers recorded at the site? | | | |
| For samplers with flow controllers? | | | Log sheet____, Dixon chart____, Other____ (specify) |
| On High-volume samplers without flow controllers? | | | Log sheet____, Dixon chart____, Other____ (specify) |
| | | | |
| | | | |
| | | | |

d) What kind of recovery capabilities for data acquisition equipment are available to the field operator after power outages, storms, etc? Briefly describe below.

(e) Using a summary flow diagram, indicate below all data handling steps performed at the air monitoring site. Identify the format, frequency and contents of data submittals to the data processing section. Clearly indicate points at which flow path differs for different criteria pollutants. Be sure to include all calibration, zero/span and precision check data flow paths. How is the integrity of the data handling system verified?

C. LABORATORY OPERATIONS

1. Routine Operations

(a) What analytical methods are employed in support of your air monitoring network?

Analysis

Methods

PM-10

Pb

PM 2.5

SO₄

NO₃

Others (list by pollutant)

| Question | Yes | No | Comment |
|---|-----|----|---|
| b) Are bubblers used for any criteria pollutants in any agencies? | | | If yes, attach a table which indicates the number of sites where bubblers are used, the agency and pollutant(s). |
| (c) Do any laboratory procedures deviate from the reference, equivalent, or approved methods? | | | If yes, are the deviations for lead analysis _____, PM-10 filter conditioning _____ or other _____ (specify below)? |
| (d) Have the procedures and/or any changes been approved by EPA? | | | Date of Approval |
| (e) Is the documentation of Laboratory SOP complete? | | | |

Complete the table below.

| Analysis | Method |
|----------------------------|--------|
| PM-10 | |
| Pb | |
| SO ₄ | |
| NO ₃ | |
| PM 2.5 | |
| Others (list by pollutant) | |

(f) Is sufficient instrumentation available to conduct your laboratory analyses? Yes___ No___ If no, please indicate instrumentation needs

| Instrument Needed | Analysis | New or Replacement | Year of Acquisition |
|-------------------|----------|--------------------|---------------------|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

2. Quality Control

a) Please complete the table for your agency's laboratory standards.

| Parameter | Primary Standard | Secondary Standard | Recertification Date |
|---------------------|------------------|--------------------|----------------------|
| CO | | | |
| NO2 | | | |
| SO2 | | | |
| O3 | | | |
| Weights | | | |
| Temperature | | | |
| Moisture | | | |
| Barometric Pressure | | | |
| Flow | | | |
| Lead | | | |
| Sulfate | | | |
| Nitrate | | | |

| Question | Yes | No | Comment |
|---|-----|----|---------|
| b) Are all chemicals and solutions clearly marked with an indication of shelf life? | | | |
| c) Are chemicals removed and properly disposed of when shelf life expires? | | | |
| d) Are only ACS chemicals used by the laboratory? | | | |

e) Comment on the traceability of chemicals used in the preparation of calibration standards.

| Question | Yes | No | Comment |
|--|-----|----|---|
| f) Does the laboratory Purchase standard solutions such as those for use with lead or other AA analysis? | | | |
| __ Make the solutions themselves? | | | |
| If the laboratory staff routinely make their own standard solutions, are procedures for such available? | | | Attach an example. |
| g) Are all calibration procedures documented? | | | Where? _____ (title) (revision) |
| Unless fully documented, attach a brief description of a calibration procedure. | | | |
| (h) Are at least one duplicate, one blank, and one standard or spike included with a given analytical batch? | | | Identify analyses for which this is routine operation |

li) Briefly describe the laboratory's use of data derived from blank analyses.

| Question | Yes | No | Comment |
|---|-----|----|---------|
| Do criteria exist which determine acceptable/non-acceptable blank data? | | | |

| Please complete the table below. | |
|----------------------------------|---------------------------|
| Pollutant | Blank Acceptance Criteria |
| SO ₂ | |
| NO ₂ | |
| SO ₄ | |
| NO ₃ | |
| Pb | |
| PM _{2.5} | |

j) How frequently and at what concentration ranges does the lab perform duplicate analysis? What constitutes acceptable agreement? Please complete the table below

| Pollutant | Frequency | Acceptance Criteria |
|-----------|-----------|---------------------|
| SO2 | | |
| NO2 | | |
| SO4 | | |
| NO3 | | |
| Pb | | |
| PM-10 | | |

(k) How does the lab use data from spiked samples? Please indicate what may be considered acceptable percentage recovery by analysis? Please complete the table below

[illegible]

| Question | Yes | No | Comment |
|--|-----|----|---|
| (l) Does the laboratory routinely include samples of reference material obtained from EPA within an analytical batch | | | If yes, indicate frequency, level, and material used. |
| (m) Are mid-range standards included in analytical batches? | | | |
| If yes, are such standards included as a QC check (span check) on analytical stability? | | | |

Please indicate the frequency, level and compound used in the space provided below

| | | | |
|---|--|--|--|
| (n) Do criteria exist for "real time quality control based on the results obtained for the mid-range standards discussed above? | | | |
|---|--|--|--|

| Question | Yes | No | Comment |
|---|-----|----|---------|
| If yes, briefly discuss them below or indicate the document in which they can be found. | | | |
| (o) Are appropriate acceptance criteria documented for each type of analysis conducted? | | | |
| Are they known to at least the analysts working with respective instruments? | | | |
| | | | |

3. Preventive Maintenance

| Question | Yes | No | Comment |
|---|-----|----|---------|
| (a) For laboratory equipment, who has responsibility for major and/or minor preventive maintenance? Person _____ Title _____ | | | |
| (b) Is most maintenance performed: in the lab? | | | |
| in the instrument repair facility? | | | |
| at the manufacturer's facility? | | | |
| (c) Is a maintenance log maintained for each major laboratory instrument? | | | Comment |
| (d) Are service contracts in place for the following analytical instruments | | | |
| Analytical Balance | | | |
| Atomic Absorption Spectrometer | | | |
| Ion Chromatograph | | | |
| Automated Colorimeter | | | |

4. Record Keeping

| Question | Yes | No | Comment |
|---|-----|----|---------|
| (a) Are all samples that are received by the laboratory logged in? | | | |
| assigned a unique laboratory sample number? | | | |
| routed to the appropriate analytical section? | | | |
| Discuss sample routing and special needs for analysis (or attach a copy of the latest SOP which covers this). Attach a flow chart if possible | | | |
| (b) Are logbooks kept for all analytical laboratory instruments? | | | |

| Question | Yes | No | Comment |
|--|-----|----|---|
| (c) Do these logbooks indicate: | | | |
| analytical batches processed? | | | |
| quality control data? | | | |
| calibration data? | | | |
| results of blanks, spikes and duplicates? | | | |
| initials of analyst? | | | |
| (d) Is there a logbook which indicates the checks made on: | | | |
| weights | | | |
| humidity indicators? | | | |
| balances? | | | |
| thermometer(s)? | | | |
| (e) Are logbooks maintained to track the preparation of filters for the field? | | | |
| Are they current? | | | |
| Do they indicate proper use of conditioning? | | | |
| Weighings? | | | |
| Stamping and numbering? | | | |
| (f) Are logbooks kept which track filters returning from the field for analysis? | | | |
| (g) How are data records from the laboratory archived? | | | |
| Where? | | | |
| Who has the responsibility? Person | | | |
| Title | | | |
| How long are records kept? Years | | | |
| (h) Does a chain-of-custody procedure exist for laboratory samples? | | | If yes, indicate date, title and revision number where it can be found. |

5. Data Acquisition and Handling

| Question | Yes | No | Comment |
|--|-----|----|---------|
| (a) Identify those laboratory instruments which make use of computer interfaces directly to record data. Which ones use stripcharts? integrators? | | | |
| (b) Are QC data readily available to the analyst during a given analytical run? | | | |
| (c) For those instruments which are computer interfaced, indicate which are backed up by stripcharts? | | | |
| (d) What is the laboratory's capability with regard to data recovery? In case of problems, can they recapture data or are they dependent on computer operations? Discuss briefly. | | | |
| (e) Has a users manual been prepared for the automated data acquisition instrumentation? | | | Comment |
| Is it in the analyst's or user's possession? | | | |
| Is it current? | | | |
| (f) Please provide below a data flow diagram which establishes, by a short summary flow chart: transcriptions, validations, and reporting format changes the data goes through before being released to the data management group. Attach additional pages as necessary. | | | |

6. Specific Pollutants: PM-10 and PM 2.5 and Lead

| Question | Yes | No | Comment |
|---|-----|----|--|
| PM10 and PM 2.5 | | | |
| (a) Are filters supplied by EPA used at SLAMS sites? | | | |
| (b) Do filters meet the specifications in the <u>Federal Register</u> 40 CFR 50? | | | |
| (c) Are filters visually inspected via strong light from a view box for pinholes and other imperfections? | | | If no, comment on way imperfections are determined? |
| (d) Are filters permanently marked with a serial number? | | | Indicate when and how this is accomplished |
| (e) Are unexposed filters equilibrated in controlled conditioning environment which meets or exceeds the requirements of 40 CFR 50? | | | If no, why not? |
| (f) Is the conditioning environment monitored? | | | Indicate frequency |
| Are the monitors properly calibrated | | | Indicate frequency |
| (g) Is the balance checked with Class "S" weights each day it is used? | | | If no, indicate frequency of such checks |
| (h) Is the balance check information placed in QC logbook? | | | If no, where is it recorded? |
| (i) Is the filter weighed to the nearest milligram? | | | If not, what mass increment |
| (j) Are filter serial numbers and tare weights permanently recorded in a bound notebook? | | | If no, indicate where |
| (k) Are filters packaged for protection while transporting to and from the monitoring sites? | | | |
| (l) How often are filter samples collected? (Indicate average lapse time (hrs.) between end of sampling and laboratory receipt.) | | | |
| (m) Are field measurements recorded in logbook or on filter folder? | | | |
| (n) Are exposed filters reconditioned for at least 24 hrs in the same conditioning environment as for unexposed filters? | | | If no, why not? |
| (o) Are exposed filters removed from folders, etc., before conditioning? | | | |
| (p) Is the exposed filter weighed to the nearest milligram? | | | |
| (q) Are exposed filters archived | | | When? Where? Indicate retention period |

| Question | Yes | No | Comment |
|--|-----|----|--|
| (r) Are blank filters reweighed? | | | If no, explain why not. If yes, how frequently? |
| (s) Are analyses performed on filters? | | | Indicate analyses other than Pb and mass which are routinely performed. |
| (t) Are sample weights and collection data recorded in a bound laboratory logbook? | | | |
| On data forms? | | | |
| (u) Are measured air volumes corrected to reference conditions as given in CFR regulations (Q_{std} of 760 mm Hg and 25 °C) prior to calculating the Pb concentration? | | | If not, indicate conditions routinely employed for both internal and external reporting |
| | | | |
| LEAD | | | |
| (a) Is analysis for lead being conducted using atomic absorption spectrometry with air acetylene flame? | | | If not, has the agency received an equivalency designation of their procedure? |
| (b) Is either the hot acid or ultrasonic extraction procedure being followed precisely? | | | Which? |
| (c) Is Class A borosilicate glassware used throughout the analysis? | | | |
| (d) Is all glassware scrupulously cleaned with detergent, soaked and rinsed three times with distilled-deionized water? | | | If not, briefly describe or attach procedure. |
| (e) If extracted samples are stored, are linear polyethylene bottles used? | | | |
| (f) Are all batches of glass fiber filters tested for background lead content? | | | |
| At a rate of 20 to 30 random filters per batch of 500 or greater? | | | Indicate rate |
| (g) Are ACS reagent grade HNO_3 and HCl used in the analysis | | | If not, indicate grade used |
| (h) Is a calibration curve available having concentrations that cover the linear absorption range of the atomic absorption instrumentation? | | | |
| (i) Is the stability of the calibration curve checked by alternately remeasuring every 10th sample a concentration 1 g Pb/ml; 10 g Pb/ml? | | | If not, indicate frequency. |
| (j) Are measured air volumes corrected to reference conditions as given in CFR regulations (Q_{std} of 760 mm Hg and 25 °C) prior to calculating the Pb concentration? | | | If not, indicate conditions routinely employed for both internal and external reporting. |
| (k) In either the hot or ultrasonic extraction procedure, is there always a 30-min H_2O soaking period to allow HNO_3 trapped in the filter to diffuse into the rinse water? | | | |

| Question | Yes | No | Comment |
|--|-----|----|---|
| (l) Is a quality control program in effect that includes periodic quantification of (1) lead in 3/4" x 8" glass fiber filter strips containing 100-300 g Pb/strip, and/or (2) a similar strip with 600-1000 g strip, and (3) blank filter strips with zero Pb content to determine if the method, as being used, has any bias? | | | Comment on lead QC program or attach applicable SOP |
| (m) Are blank Pb values subtracted from Pb samples assayed? | | | If not, explain why |

D: DATA AND DATA MANAGEMENT

1. Data Handling

| Question | Yes | No | Comment |
|--|-------------|--------|---------|
| (a) Is there a procedure, description, or a chart which shows a complete data sequence from point of acquisition to point of submission of data to EPA? | | | |
| Please provide <u>below</u> a data flow diagram indicating both the data flow within the reporting organization and the data received from the various local agencies. | | | |
| (b) Are data handling and data reduction procedures documented? | | | |
| For data from continuous analyzers? | | | |
| For data from non-continuous methods? | | | |
| (c) In what format and medium are data submitted to data processing section? Please provide separate entry for each reporting organization. | | | |
| Reporting Organization | Data Medium | Format | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

| Question | Yes | No | Comment |
|--|-----|----|-----------------------------------|
| (d) How often are data received at the processing center from the field sites and laboratory? at least once a week? _____ every 1-2 weeks? _____ once a month? _____ | | | |
| (e) Is there documentation accompanying the data regarding any media changes, transcriptions, and/or flags which have been placed into the data before data are released to agency internal data processing? Describe. | | | |
| (f) How are the data actually entered to the computer system? Digitization of stripcharts? Manual or computerized transcriptions? Other? | | | |
| (g) Is a double-key entry system used for data at the processing center? | | | |
| duplicate card decks prepared | | | If no, why not? |
| (h) Have special data handling procedures been adopted for air pollution episodes? | | | If yes, provide brief description |

2. Software Documentation

| Question | Yes | No | Comment |
|---|-----|----|--|
| (a) Does the agency have available a copy of the AIRS Manual? | | | |
| (b) Does the agency have the PARS user's guide available? | | | |
| (c) Does the Data Management Section have complete software documentation? | | | If yes, indicate the implementation date and latest revision dates for such documentation. |
| (d) Do the documentation standards follow the guidance offered by the EPA Software Documentation Protocols? | | | If no, what protocols are they based on? |
| e) What is the origin of the software used to process air monitoring data prior to its release into the SAROAD/NADB database? | | | |
| I. Purchased? | | | Supplier Date of latest version |
| II. Written in-house? | | | Latest version Date |
| III. Purchased with modifications in-house? | | | Latest version Date |
| (f) Is a user's manual available to data management personnel for all software currently in use at the agency for processing SLAMS/NAMS data? | | | |

| Question | Yes | No | Comment |
|--|-----|----|---|
| (g) Is there a functional description either: included in the user's manual? | | | |
| separate from it and available to the users? | | | |
| (h) Are the computer system contents, including ambient air monitoring data backed up regularly? | | | Briefly describe, indicating at least the media, frequency, and backup-media storage location |
| (I) What is the recovery capability (how much time and data would be lost) in the event of a significant computer problem? | | | |
| (j) Are test data available to evaluate the integrity of the software? | | | |
| Is it properly documented? | | | |

3. Data Validation and Correction

| Question | Yes | No | Comment |
|---|-----|----|--|
| (a) Have validation criteria, applicable to all pollutant data processed by the reporting organization been established and documented? | | | If yes, indicate document where such criteria can be found (title, revision date). |
| (b) Does documentation exist on the identification and applicability of flags (i.e., identification of suspect values) within the data as recorded with the data in the computer files? | | | |
| (c) Do documented data validation criteria employ address limits on and for the following: | | | |
| I. Operational parameters, such as flow rate measurements or flow rate changes | | | |
| II. Calibration raw data, calibration validation and calibration equipment tests. | | | |
| III. All special checks unique to a measurement system | | | |
| IV. Tests for outliers in routine data as part of screening process | | | |
| V. Manual checks such as hand calculation of concentrations and their comparison with computer-calculated data | | | |
| (d) Are changes to data submitted to NADB documented in a permanent file? | | | If no, why not? |

| Question | Yes | No | Comment |
|---|-----|----|--|
| (e) Are changes performed according to a documented Standard Operating Procedure or your Agency Quality Assurance Project Plan? | | | If not according to the QA Project Plan, please attach a copy of your current Standard Operating Procedure |
| (f) Who has signature authority for approving corrections? <div style="display: flex; justify-content: space-around;"> (Name) (Program Function) </div> | | | |
| (g) Are data validation summaries prepared at each critical point in the measurement process or information flow and forwarded with the applicable block of data to the next level of validation? | | | Please indicate the points where such summaries are performed. |
| (h) What criteria are applied for data to be deleted? Discuss briefly. | | | |
| (I) What criteria are applied to cause data to be reprocessed ? Discuss. | | | |
| (j) Is the group supplying data provided an opportunity to review data and correct erroneous entries? | | | If yes, how? |
| (k) Are <u>corrected</u> data resubmitted to the issuing group for cross-checking prior to release? | | | |

4. Data Processing

| Question | Yes | No | Comment |
|--|-----|----|-----------------|
| (a) Does the agency generate data summary reports? | | | |
| Are the data used for in-house distribution and use? | | | |
| Publication ? | | | Other (specify) |

| (b) Please list at least three (3) reports routinely generated, providing the information requested below | | |
|---|--------------|----------------|
| Report Title | Distribution | Period Covered |
| | | |
| | | |
| | | |

| Question | Yes | No | Comment |
|---|-------|----|---|
| (c) Have special procedures been instituted for pollution index reporting? | | | If yes, provide brief description. |
| (d) Who at the agency has the responsibility for submitting data to AIRS? | | | |
| Name | Title | | |
| Is the data reviewed and approved by an officer of the agency prior to submittal? | | | |
| (e) Are those persons different from the individuals who submit data to PARS? | | | |
| If yes, provide name and title of individual responsible for PARS data submittal. | | | |
| Name | Title | | |
| PARS data review and approval (name) | | | |
| (f) How often are data submitted to: | | | |
| AIRS ? | | | |
| PARS? | | | |
| (g) How and/or in what form are data submitted? | | | |
| TO AIRS? | | | |
| TO PARS? | | | |
| (h) Are the recommendations and requirements for data coding and submittal, in the AIRS User's Manual? | | | Comment on any routine deviations in coding procedures. |
| (f) Are the recommendations and requirements for data coding and submittal, in the PARS User's Guide, followed closely? | | | Comment on any routine deviations in coding and/or computational procedures. |
| (j) Does the agency routinely request a hard copy printout on submitted data: | | | |
| from AIRS? | | | |
| from PARS? | | | |
| (k) Are records kept for at least 3 years by the agency in an orderly, accessible form? | | | If yes, does this include raw data__, calculation__, QC data__, and reports__? If no, please comment. |
| (l) In what format are data received at the data processing center? (Specify appropriate pollutant.) | | | |
| (a) concentration units__ (b) % chart__ (c) voltages__ (d) other__ | | | |

| Question | Yes | No | Comment |
|--|-----|----|--------------------------------|
| (m) Do field data include the following documentation? | | | |
| Site ID? | | | |
| Pollutant type? | | | |
| Date received at the center? | | | |
| Collection data (flow, time date)? | | | |
| Date of Laboratory Analysis /if applicable) | | | |
| Operator/Analyst? | | | |
| (n) Are the appropriate calibration equations submitted with the data to the processing center? | | | If not, explain. |
| (o) Provide a brief description of the procedures and appropriate formulae used to convert field data to concentrations prior to input into the data bank. | | | |
| SO ₂ | | | |
| NO ₂ | | | |
| CO | | | |
| O ₃ | | | |
| PM 2.5 | | | |
| CH ₄ ,THC | | | |
| Pb | | | |
| PM 10 | | | |
| (p) Are all concentrations corrected to EPA standard (298 K, 760 mm Hg) temperature and pressure condition before input to the AIRS? | | | If no, specify conditions used |
| (q) Are data reduction audits performed on a routine basis? | | | If yes, at what frequency? |
| are they done by an independent group? | | | |
| (r) Are there special procedures available for handling and processing precision, accuracy, calibrations and span checks? | | | If no, comment |
| If yes, provide a brief description: Span checks | | | |
| Calibration data | | | |
| Precision data | | | |
| Accuracy data | | | |

| Question | Yes | No | Comment |
|--|-----|----|---|
| (s) Are precision and accuracy data checked each time they are recorded, calculated or transcribed to ensure that incorrect values are not submitted to EPA? | | | Please comment and/or provide a brief description of checks performed |
| (t) Is a final data processing check performed prior to submission of any data? | | | <p>If yes, document procedure briefly</p> <p>If no, explain</p> |

5. Internal Reporting

| | |
|--|-----------|
| (a) What reports are prepared and submitted as a result of the audits required under 40 CFR Appendix A? | |
| Report Title | Frequency |
| | |
| | |
| | |
| (Please include an example audit report and, by attaching a coversheet, identify the distribution such reports are given within the agency.) | |

| | |
|--|-----------|
| b) What internal reports are prepared and submitted as a result of precision checks also required under 40 CFR 58 Appendix A? | |
| Report Title | Frequency |
| | |
| | |
| | |
| (Please include an example of a precision check report and, identify the distribution such reports receive within the agency.) | |

| Question | Yes | No | Comment |
|--|-----|----|--|
| (c) Do either the audit or precision reports indicated include a discussion of corrective actions initiated based on audit or precision results? | | | If yes, identify report(s) and section numbers |
| (d) Does the agency prepare Precision and Accuracy summaries other than Form 1? | | | If no, please attach examples of recent summaries including a recent Form 1. |

| (e) Who has the responsibility for the calculation and preparation of data summaries? To whom are such P and A summaries delivered? | | | |
|---|-------|----------------|-----------|
| Name | Title | Type of Report | Recipient |
| | | | |
| | | | |
| | | | |

(f) Identify the individual within the agency who receives the results of the agency's participation in the NPAP and the internal distribution of the results once received.

Principal Contact for NPAP is (name, title)

Distribution

6. External Reporting

(a) For the current calendar year or portion thereof which ended at least 90 calendar days prior to the receipt of this questionnaire, please provide the following percentages for required data submitted

| %Submitted on Time* | | | | | | | |
|---------------------|-----------------|----|----------------|-----------------|-------|-------|----|
| Monitoring Qtr. | SO ₂ | CO | O ₃ | NO ₂ | PM2.5 | PM-10 | Pb |
| 1 (Jan 1-March 31) | | | | | | | |
| 2 (Apr 1- June 30) | | | | | | | |
| 3 (July 1-Sept. 30) | | | | | | | |
| 4 (Oct. 1-Dec. 31) | | | | | | | |

*"On-Time" = within 90 calendar days after the end of the quarter in which the data were collected.

(b) Identify the individual within the agency with the responsibility for preparing the required 40 CFR 58 Appendix F and G reporting inputs.

Name

Title

(c) Identify the individual within the agency with the responsibility for reviewing and releasing the data.

Name

Title

(d) Does the agency regularly report the Pollutant Standard Index (PSI)? Briefly describe the media, coverage, and frequency of such reporting.

(e) What fraction of the SLAMS sites (by pollutant) reported less than 75% of the data (adjusted for seasonal monitoring and site start-ups and terminations)?

| Percent of Sites <75% Data Recovery FY ____ | | | | |
|---|-------------|-------------|-------------|-------------|
| Pollutant | 1st Quarter | 2nd Quarter | 3rd Quarter | 4th Quarter |
| Ozone | | | | |
| Nitrogen Dioxide | | | | |
| Sulfur Dioxide | | | | |
| Carbon Monoxide | | | | |

| | | | | |
|-------|--|--|--|--|
| PM-10 | | | | |
| PM2.5 | | | | |
| Lead | | | | |

| Question | Yes | No | Comment |
|---|-----|----|---------|
| (f) Does the agency's annual report (as required in 40 CFR 58.26) include the following? | | | |
| Data summary required in Appendix F | | | |
| Annual precision and accuracy information described in Section 5.2 of Appendix A. | | | |
| Location, date, pollution source and duration of all episodes reaching the significant harm levels. | | | |
| Certification by a senior officer in the State or his designee. | | | |
| (g) Please provide the dates at which the annual reports have been submitted for the last 2 years. | | | |

E. QUALITY ASSURANCE/QUALITY CONTROL

1. Status of Quality Assurance Program

| Question | Yes | No | Comment |
|--|-----|----|-----------------|
| (a) Does the agency have an EPA-approved quality assurance program plan? | | | |
| If yes, have changes to the plan been approved by the EPA? | | | |
| <div style="display: flex; justify-content: space-between; padding: 5px;"> Please provide: Date of Original Approval Date of Last Revision Date of Latest Approval </div> | | | |
| b) Do you have any revisions to your QA Program Plan still pending? | | | |
| (c) Is the QA Plan fully implemented? | | | |
| (d) Are copies of QA Plan or pertinent sections available to agency personnel? | | | If no, why not? |
| (e) Which individuals routinely receive updates to QA Plan? | | | |

2. Audits and Audit System Traceability

| Question | Yes | No | Comment |
|---|-----|----|--|
| (a) Does the agency maintain a separate audit/calibration support facility laboratory? | | | |
| (b) Has the agency documented and implemented specific audit procedures? | | | |
| (c) Have audit procedures been prepared in keeping with the requirements of Appendix A to 40 CFR 58? | | | |
| (d) Do the procedures meet the specific requirements for independent standards and the suggestions regarding personnel and equipment? | | | |
| (e) Are SRM or CRM materials used to routinely certify audit materials? | | | |
| (f) Does the agency routinely use NIST-SRM or CPM materials? | | | For audits only?__ For calibrations only?__ For both?__ For neither, secondary standards are employed__ |
| (g) Does the agency audit the Meteorological sites? | | | |
| | | | |

(g) Please list below areas routinely covered by this review, the date of the last review, and changes made as a direct result of the review.

| Pollutants | Audit Method | Audit Standard |
|-----------------|--------------|----------------|
| CO | | |
| O ₃ | | |
| NO ₂ | | |
| SO ₂ | | |
| PM-10 | | |
| PM 2.5 | | |

| Question | Yes | No | Comment |
|--|-----|----|--|
| (h) Are SRM or CRM materials used to establish traceability of calibration and zero/span check materials provided to field operations personnel? | | | |
| (i) Specifically for gaseous standards, how is the traceability of audit system standard materials established? | | | |
| Are they: purchased certified by the vendor? | | | |
| certified by the QA support laboratory which is part of this agency? | | | |
| (j) Are all agency traceability and standardization methods used documented? | | | Indicate document where such methods can be found. |
| (k) Do the traceability and standardization methods conform with the guidance of VOL. II of the Handbook for Air Pollution Measurement Systems? | | | |
| For permeation devices? | | | |
| For cylinder gases? | | | |
| (l) Does the agency have identifiable auditing equipment (specifically intended for sole use) for audits? | | | If yes, provide specific identification |
| (m) How often is auditing equipment certified for accuracy against standards and equipment of higher authority? | | | |

(n) As a result of the audit equipment checks performed, have pass/fail (acceptance criteria) been decided for this equipment? Indicate what these criteria are with respect to each pollutant. Where are such criteria documented?

| Pollutant | Criteria |
|-----------|----------|
| | |
| | |

3. National Performance Audit Program (NPAP) And Additional Audits

(a) Identify the individual with primary responsibility for the required participation in the National Performance Audit Program.

For gaseous materials? (name, title)

For laboratory materials? (name, title)

| Question | Yes | No | Comment |
|--|----------------|----|---------|
| (b) Does the agency currently have in place any contracts or similar agreements either with another agency or outside contractor to perform any of the audits required by 40 CFR 58? | | | |
| If yes, has the agency included QA requirements with this agreement? | | | |
| Is the agency adequately familiar with their QA program? | | | |
| (c) Date last systems audit was conducted | Date: By Whom: | | |

| (d) Please complete the table below | |
|-------------------------------------|-------------------|
| Parameter Audited | Date of Last NPAP |
| SO ₂ | |
| CO | |
| Pb | |
| PM-10 | |
| O ₃ | |
| NO ₂ | |
| | |

| Question | Yes | No | Comment |
|--|-----|----|----------------------------------|
| (e) Does the agency participate in the National Performance Audit Program (NPAP) as required under 40 CFR 58 Appendix A? | | | If no, why not? Summarize below. |

4. Documentation and Data Processing Review

| Question | Yes | No | Comment |
|--|-----|----|---------|
| (a) Does the agency periodically review its record-keeping activities? | | | |

Please list below areas routinely covered by this review, the date of the last review, and changes made as a direct result of the review.

| Area/Function | Date of Review | Changes? (Y/N) | Discuss Changes |
|---------------|----------------|-------------------|-----------------|
| | | | |
| | | | |
| | | | |

| Question | Yes | No | Comment |
|--|-----|----|------------------------|
| (b) Are data audits (specific re-reductions of strip charts or similar activities routinely performed for criteria pollutants data reported by the agency? | | | If no, please explain. |
| (c) Are procedures for such data audits documented? | | | |
| (d) Are they consistent with the recommendations of Sections 16.4.2.3 of Vol. II of the QA Handbook for Air Pollution Measurement Systems? | | | If no, why not? |

(e) What is the frequency and level (as a percentage of data processed of these audits?

| Pollutant | Audit Frequency | Period of Data Audited | % of Data Rechecked |
|-----------|-----------------|------------------------|---------------------|
| | | | |
| | | | |
| | | | |
| | | | |

(f) Identify the criteria for acceptable/non-acceptable result from a data processing audit for each pollutant, as appropriate

| Pollutant | Acceptance Criteria | Data Concentration Level |
|-----------|---------------------|--------------------------|
| | | |
| | | |
| | | |
| | | |

6. Audit Result Acceptance Criteria

| Question | Yes | No | Comment |
|--|-----|----|---------|
| (a) Has the agency established and has it documented criteria to define agency-acceptable audit results? | | | |
| | | | |
| | | | |

| Please complete the table below with the pollutant, monitor and acceptance criteria. | |
|--|----------------------------------|
| Pollutant | Audit Result Acceptance Criteria |
| CO | |
| O ₃ | |
| NO ₂ | |
| SO ₂ | |
| PM-10. | |
| PM2.5 | |

| Question | Yes | No | Comment |
|---|-----|----|--|
| (b) Were these audit criteria based on, or derived from, the guidance found in Vol. I. II of the QA Handbook for Air Pollution Measurement System, Section 2.0.12? | | | <p>If no, please explain.</p> <p>If yes, please explain any changes or assumptions made in the derivation.</p> |
| <p>(c) What corrective action may be taken if criteria are exceeded? If possible, indicate two examples of corrective actions taken within the period since the previous systems audit which are based directly on the criteria discussed above.</p> <p>Corrective Action # 1</p> <p>Corrective Action #2</p> | | | |

(d) As a goal, the 95 percent probability limits for precision (all pollutants) and PM-10 accuracy should be less than + 15 percent. At 95 percent probability limits, the accuracy for all other pollutants should be less than +20 percent. Using a short narrative and a summary table, compare the reporting organizations performance against these goals over the last year. Explain any deviations.

NOTE: Precision and accuracy are based on reporting organizations; therefore this question concerns the reporting organizations that are the responsibility of the agency. Complete the tables below indicating the number of reporting organizations meeting the goal stated above for each pollutant by quarter

| I. Precision Goals (Report level 2 checks unless otherwise directed by Regional Office.) | | | | | |
|---|-----------------------------|--------|--------|--------|--------|
| Pollutant | # of Reporting Organization | Qtr/Yr | Qtr/Yr | Qtr/Yr | Qtr/Yr |
| CO | | | | | |
| O ₃ | | | | | |
| NO ₂ | | | | | |
| SO ₂ | | | | | |
| PM-10. | | | | | |
| PM2.5 | | | | | |
| Pb | | | | | |

| I. Accuracy Goals (Report level 2 checks unless otherwise directed by Regional Office.) | | | | | |
|--|-----------------------------|--------|--------|--------|--------|
| Pollutant | # of Reporting Organization | Qtr/Yr | Qtr/Yr | Qtr/Yr | Qtr/Yr |
| CO | | | | | |
| O ₃ | | | | | |
| NO ₂ | | | | | |
| SO ₂ | | | | | |
| PM-10. | | | | | |
| PM2.5 | | | | | |
| Pb | | | | | |

(e) To the extent possible, describe problems preventing the meeting of precision and accuracy goals.

1000 APPENDICES

**Ambient
Air
Monitoring**

APPENDIX E

SITE INITIATION AND TERMINATION REPORT FORM

SITE IDENTIFICATION REPORT FORM

PROBE AND SAMPLER IDENTIFICATION REPORT FORM

POLLUTANT AND PROJECT IDENTIFICATION REPORT FORM

SITE SURVEY FORM

Site Initiation/Termination Report

I. New Site or Parameter

Provide the reason(s) for establishing air monitoring site or initiating new parameters. Specify applicable federal or state standards, the objectives or the monitoring, and the expected duration of monitoring.

II. Initiation/Termination Dates

Begin Date: ____/____/____; End Date: ____/____/____

III. Terminate Site or Parameters

Provide the reason for terminating air monitoring site or parameter

IV. Pollutant Information

| Pollutant | Spatial Scale | | | | | Monitoring Type | | | | |
|-------------------|---------------|--------|--------|-------|--------|-----------------|-------|------|-----|-----|
| | Micro | Middle | Neigh. | Urban | Region | NAMS | SLAMS | PAMS | SPM | PSD |
| Ozone | | | | | | | | | | |
| CO | | | | | | | | | | |
| NO ₂ | | | | | | | | | | |
| SO ₂ | | | | | | | | | | |
| PM ₁₀ | | | | | | | | | | |
| PM _{2.5} | | | | | | | | | | |
| Lead | | | | | | | | | | |

V. Signatures

Prepared By _____ Site Name _____

Title _____ Site Number _____

Date ____/____/____ Effective Date ____/____/____

Site Identification Report

Attach an 8 1/2" x 11" portion of a U.S. Geological Survey or local street map indicating the site location, and photographs of the four quadrants surrounding the site.

| | | | | | |
|---|--|---|--|---|--|
| Report completed by: | | Date _/_/___ | | This report: <input type="checkbox"/> Is for a new or relocated probe or sampler <input type="checkbox"/> Amends a previous report | |
| For ARB Use Only | | | | | |
| Action <input type="checkbox"/> Card No. A | | Site Name (as assigned by the ARB) <div style="border: 1px solid black; height: 15px; width: 100%;"></div> | | | |
| County <div style="border: 1px solid black; width: 20px; height: 15px; display: inline-block;"></div> Site Number Type <div style="border: 1px solid black; width: 20px; height: 15px; display: inline-block;"></div> Site <div style="border: 1px solid black; width: 20px; height: 15px; display: inline-block;"></div> | | To Be Completed By Reporting Agency | | | |
| Basin Code <div style="border: 1px solid black; width: 20px; height: 15px; display: inline-block;"></div> Responsible Agency Code <div style="border: 1px solid black; width: 20px; height: 15px; display: inline-block;"></div> | | Agency Responsible for Site <div style="border: 1px solid black; height: 15px; width: 100%;"></div> | | | |
| | | Site Location (air basin) County <div style="border: 1px solid black; height: 15px; width: 100%;"></div> | | | |
| | | Geographical Coordinates (Enter Longitude & Latitude or UTM Coord) <div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> Longitude Deg. Min. Sec. <div style="border: 1px solid black; width: 20px; height: 15px; display: inline-block; text-align: center;">00</div> <div style="border: 1px solid black; width: 20px; height: 15px; display: inline-block; text-align: center;">W</div> </div> <div style="width: 45%;"> Latitude Deg. Min. Sec. <div style="border: 1px solid black; width: 20px; height: 15px; display: inline-block; text-align: center;">N</div> </div> </div> | | | |
| | | UTM Zone Easting Coord. (meters) Northing Coord. (meters) <div style="border: 1px solid black; width: 20px; height: 15px; display: inline-block;"></div> <div style="border: 1px solid black; width: 20px; height: 15px; display: inline-block;"></div> <div style="border: 1px solid black; width: 20px; height: 15px; display: inline-block;"></div> | | | |

Probe/Sampler Identification Report

- This report is to be completed when installing or relocating any probe (air sampling system, wind sensor, or individual sampler such as hi-vol, tape sampler, etc.) at the site identified below. The individual who is relocating or installing a probe or sampler is to assign a two digit code (probe/sampler identification code) which is unique to that site. A new probe/sampler identification code will be assigned each time a probe or sampler is relocated or altered.
- Attach a dimensioned schematic showing: A) the configuration of each probe and distribution manifold; B) the location of each individual sampler in respect to other samplers; and C) and obstructions which meet the criteria presented below. Identify on the schematic the probe/sampler ID code and the pollutants sampled from each probe or sampler.

| | | | | |
|---|--|--|---|---|
| Report completed by: _____ | Date ____/____/____ | This report: <div style="display: flex; justify-content: space-between; margin-top: 10px;"> <input type="checkbox"/> Is for a new or relocated probe or sampler <input type="checkbox"/> Amends a previous report </div> | | |
| For ARB Use Only | To Be Completed By Reporting Agency | | | |
| Action <input type="checkbox"/> Card No. F <div style="text-align: center;">Site Number</div> <div style="display: flex; justify-content: space-around;"> <div>County <input type="checkbox"/></div> <div>Type <input type="checkbox"/></div> <div>Site <input type="checkbox"/></div> </div> <div style="display: flex; justify-content: space-around; margin-top: 10px;"> <div>Probe/Sampler Identification Code <input type="checkbox"/></div> <div>Sampler Category <input type="checkbox"/></div> </div> | Site Name (as assigned by the ARB) _____ Site Address (number, street, city) _____ <div style="display: flex; justify-content: space-between;"> Site Location (air basin) _____ <div>County _____</div> </div> | | | |
| Action <input type="checkbox"/> Card No. G <div style="display: flex; justify-content: space-around;"> <div>Operating Period Code <input type="checkbox"/></div> <div>Obstruction "1" if Yes <input type="checkbox"/></div> </div> <div style="display: flex; justify-content: space-around; margin-top: 10px;"> <div>Dir. Nearest Street <input type="checkbox"/></div> <div>Dist. Manifold "1" if Yes <input type="checkbox"/></div> </div> <div style="display: flex; justify-content: space-around; margin-top: 10px;"> <div>Orientation Of Air Intake <input type="checkbox"/></div> <div>Material Probe <input type="checkbox"/></div> <div>Dist Manifold <input type="checkbox"/></div> </div> | Enter the probe/sampler identification code. Code must correspond to the respective code designated on the attached schematic <input type="checkbox"/> <input type="checkbox"/> <div style="display: flex; justify-content: space-between;"> <div style="width: 30%;"> Operating Period (either initiate or terminate date) Initiate Year <input type="checkbox"/><input type="checkbox"/> month <input type="checkbox"/><input type="checkbox"/> Terminate Year <input type="checkbox"/><input type="checkbox"/> month <input type="checkbox"/><input type="checkbox"/> </div> <div style="width: 20%;"> Intake/wind sensor/sampler height above ground (m) <input type="checkbox"/><input type="checkbox"/><input type="checkbox"/><input type="checkbox"/> </div> <div style="width: 40%;"> Horizontal distance of intake/wind sensor/sampler to nearest street (m) <input type="checkbox"/><input type="checkbox"/><input type="checkbox"/><input type="checkbox"/> </div> </div> <div style="margin-top: 10px;"> Distance of intake/wind sensor/sampler Above roof level. If below roof level enter ">" in box labeled "above/below", otherwise leave the box blank <div style="display: flex; justify-content: space-between;"> <div>distance (m) above/below</div> <div><input type="checkbox"/><input type="checkbox"/> <input type="checkbox"/><input type="checkbox"/></div> </div> </div> <div style="margin-top: 10px;"> Direction of the nearest street from the air intake/sampler <div style="display: flex; flex-wrap: wrap;"> <div style="width: 25%;"><input type="checkbox"/> 1. N</div> <div style="width: 25%;"><input type="checkbox"/> 2. NE</div> <div style="width: 25%;"><input type="checkbox"/> 3. E</div> <div style="width: 25%;"><input type="checkbox"/> 4. SE</div> <div style="width: 25%;"><input type="checkbox"/> 5. S</div> <div style="width: 25%;"><input type="checkbox"/> 6. SW</div> <div style="width: 25%;"><input type="checkbox"/> 7. W</div> <div style="width: 25%;"><input type="checkbox"/> 8. NW</div> </div> </div> | | | |
| Typical air sampling system | If a line extended 30° up from the horizontal at the intake/wind sensor/ sampler and rotated 360° intersects any obstruction within 30 meters, give identifying information below: <div style="display: flex; justify-content: space-between; margin-top: 10px;"> <div>Obstruction</div> <div>Direction</div> <div>Distance</div> </div> | | | |
| Complete for Continuous Sampling probes and Tape Samplers Only | | | | |
| Probe inside diameter (mm) <input type="checkbox"/> <input type="checkbox"/> | Flowrate (l/min) <input type="checkbox"/> <input type="checkbox"/> | Total probe length (m) <input type="checkbox"/> <input type="checkbox"/> | Residence time (sec) <input type="checkbox"/> <input type="checkbox"/> | Distance from wall (m) <input type="checkbox"/> <input type="checkbox"/> |
| Number of samples distrib. From Probe <input type="checkbox"/> <input type="checkbox"/> | Is a distribution manifold used? Yes <input type="checkbox"/> No <input type="checkbox"/> | Manifold inside diameter (mm) <input type="checkbox"/> <input type="checkbox"/> | Manifold length (m) <input type="checkbox"/> <input type="checkbox"/> | |
| Orientation of air intake <div style="display: flex; justify-content: space-between;"> <input type="checkbox"/> 1. Vertical <input type="checkbox"/> 2. Down <input type="checkbox"/> 3. Horizontal </div> | | | | |
| Probe material <div style="display: flex; justify-content: space-between;"> <input type="checkbox"/> 1. Teflon <input type="checkbox"/> 2. Glass <input type="checkbox"/> 3. Other </div> | | | | |
| Distribution manifold material <div style="display: flex; justify-content: space-between;"> <input type="checkbox"/> 1. Teflon <input type="checkbox"/> 2. Glass <input type="checkbox"/> 3. Other </div> | | | | |

Pollutant/Project Identification Report

One of these reports must be submitted upon installation or relocation of any sampling instrument

| | | |
|--|--|---|
| Report completed by: _____ | Date ____/____/____ | This report: <div style="display: flex; justify-content: space-between; margin-top: 5px;"> <input type="checkbox"/> Is for a new or relocated probe or sampler <input type="checkbox"/> Amends a previous report </div> |
| For ARB Use Only <div style="margin-top: 10px;"> Action <input type="checkbox"/> Card No. H </div> <div style="margin-top: 10px;"> Site Identification Code County Type Site </div> <div style="margin-top: 10px;"> Agency Project </div> <div style="margin-top: 10px;"> AIRS Identification Code State County Site Agency </div> | To Be Completed By Reporting Agency <div style="margin-top: 5px;"> The Information Presented Below Will Be Used To Establish The Category (Project) Into Which the Data For The Specified Pollutants Will Be Entered Purpose Of Sampling (Ambient Monitoring, Special Study, Etc.) </div> <div style="margin-top: 5px;"> Site Name (As Assigned By The ARB) </div> <div style="margin-top: 5px;"> Site Address (Number, Street, City) </div> <div style="margin-top: 5px;"> Site Location (Air Basin) County </div> <div style="margin-top: 5px;"> Agency Responsible For Data Submission </div> | |
| <div style="margin-top: 10px;"> Action <input type="checkbox"/> Card No. I </div> <div style="margin-top: 10px;"> ARB Pollutant Code Pollutant Method Units </div> <div style="margin-top: 10px;"> Time Interval Sampling Period Code Manufacturer Identification Code </div> <div style="margin-top: 10px;"> ARB Publish EPA/NASN Report EPA Site Type NAQTS SLAMS </div> | <div style="margin-top: 5px;"> Pollutant Sampling Information Below Pertains To The "Purpose Of Sampling Described Above" </div> <div style="margin-top: 5px;"> Pollutant Sampled </div> <div style="margin-top: 5px;"> <div style="display: flex; justify-content: space-between;"> <div>Collection/Analysis Method</div> <div>Reporting Units</div> </div> </div> <div style="margin-top: 5px;"> <div style="display: flex; justify-content: space-between;"> <div>Instrument Manufacturer</div> <div>Model No.</div> </div> </div> <div style="margin-top: 5px;"> <div style="display: flex; justify-content: space-between;"> <div> Sampling Period (Either Initiate Or Terminate Date) Initiate Date Terminate Date Year Month Year Month </div> <div> Instrument Property Number <div style="border: 1px solid black; display: inline-block; width: 40px; height: 15px;"></div> </div> </div> </div> | |
| <div style="margin-top: 10px;"> Action <input type="checkbox"/> Card No. I </div> <div style="margin-top: 10px;"> ARB Pollutant Code Pollutant Method Units </div> <div style="margin-top: 10px;"> Time Interval Sampling Period Code Manufacturer Identification Code </div> <div style="margin-top: 10px;"> ARB Publish EPA/NASN Report EPA Site Type NAQTS SLAMS </div> | <div style="margin-top: 5px;"> Pollutant Sampling Information Below Pertains To The "Purpose Of Sampling" Described Above </div> <div style="margin-top: 5px;"> Pollutant Sampled </div> <div style="margin-top: 5px;"> <div style="display: flex; justify-content: space-between;"> <div>Collection/Analysis Method</div> <div>Reporting Units</div> </div> </div> <div style="margin-top: 5px;"> <div style="display: flex; justify-content: space-between;"> <div>Instrument Manufacturer</div> <div>Model No.</div> </div> </div> <div style="margin-top: 5px;"> <div style="display: flex; justify-content: space-between;"> <div> Sampling Period (Either Initiate Or Terminate Date) Initiate Date Terminate Date Year Month Year Month </div> <div> Instrument Property Number <div style="border: 1px solid black; display: inline-block; width: 40px; height: 15px;"></div> </div> </div> </div> | |

SITE SURVEY PROGRAM

PROBLEM:

To generate accurate and representative data, air monitoring stations should meet current siting requirements and conditions. A detailed analysis of siting conditions, being conducted during our audits, indicates the data from the ambient air monitoring stations, at times, do not meet Environmental Protection Agency (EPA) and Air Resources Board (ARB) siting standards.

BACKGROUND:

It is assumed that the stations met the then existing siting criteria when they began operation. As such, non-conformance today is the result of changing regulations and changes in surrounding conditions and land use. The siting requirements of the ARB's Quality Assurance (QA) Manual Volume II; 40 CFR 58, Appendix E; EPA's Quality Assurance Handbook Volume IV; EPA Prevention of Significant Deterioration (PSD); and Photochemical Assessment Monitoring Stations (PAMS) guidelines, present siting criteria to ensure the collection of accurate and representative data.

Some of the EPA's siting criteria are stated as "must meet" and some are stated as "should meet". According to 40 CFR 58, Appendix E, the "must meet" requirements are necessary for high quality data. Any exception from the "must meet" requirements must be formally approved through the Appendix E waiver provision (Section 11). The "should meet" criteria establish a goal for data consistency.

The siting criteria for each pollutant vary depending on the pollutant's properties and the requirements addressed in the guideline documents. In the accompanying tables (Tables 1-15), the impact and effect on data representativeness or accuracy of violating siting criteria is briefly described. The impact of deviation from the siting criteria has been deduced from the aspects of air monitoring that would be influenced by the deviation. Likewise, the effect of the deviation has been deduced from whether the deviation would influence the representativeness (accurately monitoring the air mass, but the air mass monitored may not be the one desired) and accuracy (the monitors are not properly sampling the air mass). The EPA status (must/should) is also listed. The sources of the pertinent rules are listed under the "Rule" heading. A rule from 40 CFR 58, Appendix E is abbreviated as "E Rule-Number", (i.e., a criterion found in 40 CFR 58, Appendix E, Section 8.1 is abbreviated as E8.1). A siting criterion found in the ARB's QA Manual, EPA's QA Handbook Volume IV, EPA's PSD, and PAMS guidelines are abbreviated as QA II, Vol IV, PSD, and PAMS, respectively. The final column of the tables describes whether an Air Quality Data Action (AQDA) request or warning should be issued.

In Table 1 the various particulate matter (PM10) sampler types (SSI, Dichot, TEOM, BAM, AISI, and Nephelometer) are grouped together since they are all different ways of measuring the same pollutant. Similarly, lead and TSP are grouped in Table 2 since lead is analyzed on the TSP fraction.

Tables 3 through 6 address O3, CO, NO2, and SO2 siting criteria, respectively.

Table 7 addresses the siting criteria for H2S monitoring. Siting criteria for SO2 were used for H2S as a compromise since no criteria exist specifically for H2S monitoring. Since there are no specific siting criteria for H2S monitoring, a warning is appropriate for most siting discrepancies, except those effecting accuracy. The probe material, residence time, in-line filter, and station temperature effect the accuracy of the data collected, therefore an AQDA will be issued for violations.

Siting criteria for THC, CH4, and NMOC are based on PAMS guidelines and 40 CFR 58, Appendix E requirements and included with PAMS on Table 8. Criteria for wet and dry acid deposition (Tables 9 and 10) and Toxics monitoring (Tables 11 and 12) are based on requirements from the ARB QA Manuals.

Meteorological monitoring (temperature, relative humidity, wind speed, wind direction, and solar radiation [Tables 13-15]) siting criteria are based on conditions specified in PSD, EPA QA Handbook Volume IV, and the ARB QA Manual. A table was not generated for barometric pressure since it is relatively immune to siting conditions, and there are no siting specifications.

A waiver of 40 CFR 58, Appendix E criteria may be requested from EPA Region IX by the ARB, however, the EPA intends to be sparing about approving waivers. Requests for a waiver must be very well documented, emphasizing why the criteria cannot be met and demonstrating that the data are representative of monitoring objectives. Cost benefits, historical trends, etc., can be weighed as factors, but cannot be the sole reason for a waiver.

The EPA will take into account the effect the deviation has on the measurements, especially to the pollutants of primary concern at a monitoring site. Thus, for example, if a siting factor for particulate matter is not met, but the primary purpose of the site is to monitor SO2 concentrations, the EPA will be more amenable to a waiver of the particulate matter siting criterion.

The EPA will also take into account wind direction. A site must be free of impairments in the windward direction of pollutant sources.

The EPA will also be more lenient about approving a waiver if a pollutant concentration is consistently well above or well below the ambient air quality standards. If a site is issued a waiver, the waiver will be reevaluated if the concentrations change to be close to the standard and could be a factor in attainment/non-attainment designations.

IMPLEMENTATION:

Site Reports

The information from site reports generated by monitoring stations for site initiations or modifications will be entered into a new site survey record, or appended to any existing site survey record. The information will be evaluated and discussed with the site operator. If necessary, an AQDA or warning will be issued. If information is added to a site survey from a site report amendment, the items entered will be noted under action items to be checked and confirmed in the field.

Site Reviews

A site review will consist of field review and verification of siting conditions. If there is no site survey on file, the site review will entail collecting and entering all information and measurements about a site. If a partial site survey is on file (for example, data entered from the site report), the site review will entail review and confirmation of existing data, and augmentation with the remaining required data. Any discrepancies from the information from the site reports will be noted in the comments section. Such discrepancies will be investigated to establish the correct information. If necessary, the site operator will be requested to submit an amended site report.

If there is a complete site survey on file, the information and measurements will be reviewed and confirmed for continued accuracy. Any changes will be noted on the site survey form, and with a note in the comments section. Discrepancies from siting criteria will be noted in the action items section.

Discrepancies from the siting criteria will be evaluated and an AQDA or warning issued if necessary.

AQDA/Warning Issuance

If necessary, AQDAs and warnings will be issued for deficiencies noted in the site reviews, or reviews of site reports.

If a siting criteria deficiency is found during review of the site report for a new or modified monitoring station, the deficiency will be discussed with the site operator. If the site operator confirms the siting criteria deficiency, they will be informed of the impact of the deficiency on data quality and advised to correct the problem. Data will not be accepted from a new station that does not meet siting criteria.

In the case where a siting criteria deficiency is found during a site review, the site operator will be informed of the deficiency at the time it is found. The conditions not meeting the siting criteria will be discussed with the operator. The operator will also be informed whether the deficiency is an AQDA or warning item.

If an AQDA level deficiency is found at the site, the auditors will confirm that the condition requires an AQDA when they return to the office, and the QA section manager will be informed of the intent to issue the AQDA. The AQDA will be logged, assigned a tracking number, and an AQDA letter will be generated for the QA section manager's signature.

Similarly, if a warning level siting criteria deficiency is found at the site, the auditors will confirm the condition meets the warning conditions when they return to the office, and the QA section manager will be informed of the intent to issue the warning. An Air Quality Data Warning (AQDW) letter, similar to the AQDA letter, will be mailed to the site operator requesting correction of the warning level deficiency. The AQDW will be tracked to monitor corrective action. The warning will also be included in the final audit report letter to the agency.

AQDA Resolution

The action necessary to resolve a siting criteria AQDA can be as simple as trimming trees, raising the inlet height, or increasing the probe flowrate; or as extensive as complete renovation or relocation of the monitoring station. In many cases an amended site report will be required.

An amended site report will serve as documentation of corrective action taken to resolve a siting criteria AQDA. As with all information from site reports, the amended site report data will need to be checked by site review during the next audit or readit.

Since we had not been enforcing the siting requirements, and we are primarily interested in correcting deficiencies, data deletion should be examined on a case by case basis. If an AQDA is issued and no corrective action is taken, we should begin data deletion at the date at which it can be shown that the non-conforming condition began.

In some cases, such as in separation distance from traffic, the station operator may opt to change the category or scale description of the station to meet the requirements as is. Whether this is allowed under the State Implementation Plan (SIP), or other monitoring plans, must be determined by the agency operating the site before requesting the change.

As a third alternative, a waiver could be applied for under 40 CFR 58, Appendix E, Section 11. Whether the EPA approves a waiver depends on how sensitive the monitoring is to the noncompliant condition, the reason monitoring is being conducted, and the ambient concentration levels relative to the ambient air quality standards. The EPA would prefer the condition be corrected rather than the requirement waived; therefore, the EPA does not plan to be generous with waivers. However, the EPA wants to preserve data if at all possible.

Warning Resolution

Resolution of warnings will be similar to the resolution of AQDAs, except data deletion will not be involved. The actions necessary by the site operator are the same. Corrective action will be requested when discussing the warning condition with the operator. The final audit report letter to the agency will also request a response detailing the action taken to correct the condition.

RECOMMENDATIONS:

We need to walk a fine line between accepting non-representative data and possibly deleting years worth of data. At this point, we should issue an AQDA for not meeting the "must meet" criteria and a warning for not meeting the "should meet" criteria. In addition, any siting conditions adversely influencing the accuracy of the data should result in an AQDA. If a siting factor only impacts representativeness, it should result in a warning rather than an AQDA, unless the item carries an EPA "must meet" classification. The attached tables delineate the site survey items, their potential impact and effect, whether the item is an EPA "must meet" or "should meet" item, and whether noncompliance should result in an AQDA or a warning.

We should issue AQDAs and warnings and request action be taken to correct all siting deficiencies. If we do not issue AQDAs or warnings, corrective action is probably unlikely to be forthcoming. However, we do not want to disrupt monitoring projects unnecessarily in order to correct minor siting criteria conditions.

The conditions resulting in the AQDA or warning, and the corrective action taken, should be coordinated with the appropriate air monitoring section. If the corrective action entails relocation or reclassification of the station, it should also be coordinated with the ARB's Technical Support Division. Copies of the Site Survey are currently being forwarded to the air monitoring sections for their information.

In staff discussions with the EPA, the EPA has expressed the desire to do everything possible to preserve data while maintaining the quality of the data acquired. The above procedures would assure the ambient air monitoring stations are up to conformance with the siting criteria. New stations would be required to meet all criteria before their data are accepted.

Table 1

Air Monitoring Siting Criteria

Parameter : PM10 (SSI), Dichot, TEOM, BAM, AISI, Nephelometer

| Item | Impact | Effect | EPA Status | Rule | Action |
|--------------------------|---------------------------------|--------------------|-----------------|------|---------|
| Ground Cover | Possible contamination | Representativeness | Should | E8.1 | Warning |
| Height | Spatial regime sampled | Representativeness | Must | E8.1 | AQDA |
| Spacing between samplers | Spatial regime and interference | Accuracy | Must | A3.3 | AQDA |
| Boom length | NA | | | | |
| position | NA | | | | |
| orientation | NA | | | | |
| Radiation shield | NA | | | | |
| Obstacles | Spatial regime / Airflow | Representativeness | Must | E8.2 | AQDA |
| Dripline | Destructive interference | Accuracy | Should / Must * | E8.2 | AQDA |
| Walls, Parapet, etc. | Spatial regime / Airflow | Representativeness | Must | E8.2 | AQDA |
| Air flow arc | Spatial regime / Airflow | Representativeness | Must | E8.2 | AQDA |
| Local sources | Possible contamination | Representativeness | Should | E8.2 | Warning |
| Flues | Possible contamination | Representativeness | Should | E8.2 | Warning |
| Traffic | Spatial scale ** | Representativeness | Must | E8.3 | AQDA |
| Probe material | NA | | | | |
| Probe residence time | NA | | | | |
| Inline filter | NA | | | | |
| Station temperature | NA | | | | |

* Should be 20 meters from general dripline of trees, must be 10 m from dripline if the tree is considered an obstacle

** Acceptable distance from traffic related to volume of traffic and scale of monitoring (see Figure 2; 40 CFR 58, Appendix E)

NA - Not Applicable

Rule E#.# - Rule found in 40 CFR 58, Appendix E, Section #.#

Table 2

Air Monitoring Siting Criteria

Parameter : Lead, TSP

| Item | Impact | Effect | EPA Status | Rule | Action |
|--------------------------|---------------------------------|--------------------|-----------------|------|---------|
| Ground Cover | Possible contamination | Representativeness | Should | E7.1 | Warning |
| Height | Spatial regime sampled | Representativeness | Must | E7.1 | AQDA |
| Spacing between samplers | Spatial regime and interference | Accuracy | Must | A3.3 | AQDA |
| Boom length | NA | | | | |
| position | NA | | | | |
| orientation | NA | | | | |
| Radiation shield | NA | | | | |
| Obstacles | Spatial regime / Airflow | Representativeness | Must | E7.2 | AQDA |
| Dripline | Destructive interference | Accuracy | Should / Must * | E7.4 | AQDA |
| Walls, Parapet, etc. | Spatial regime / Airflow | Representativeness | Must | E7.2 | AQDA |
| Air flow arc | Spatial regime / Airflow | Representativeness | Must | E7.2 | AQDA |
| Local sources | Possible contamination | Representativeness | Should | E7.2 | Warning |
| Flume | Possible contamination | Representativeness | Should | E7.2 | Warning |
| Traffic | Spatial scale ** | Representativeness | Must | E7.3 | AQDA |
| Probe material | NA | | | | |
| Probe residence time | NA | | | | |
| Inline filter | NA | | | | |
| Station temperature | NA | | | | |

* Micro and middle scale category (a) sites - must be no trees between source and sampler

Neighborhood scale category (b) sites - should be 20 meters from general dripline and must be at least 10 m from trees that act as obstructions

** Acceptable distance from traffic related to volume of traffic and scale of monitoring (see Table 4; 40 CFR 58, Appendix E)

NA - Not Applicable

Rule E#.# - Rule found in 40 CFR 58, Appendix E, Section #.#

Table 3

Air Monitoring Siting Criteria

Parameter : Ozone

| Item | Impact | Effect | EPA Status | Rule | Action |
|------------------------------|--|--------------------|-----------------|------------|--------|
| Ground Cover | NA | | | | |
| Height | Spatial regime sampled | Representativeness | Must | E5.1 | AQDA |
| Spacing between samplers | NA | | | | |
| Boom length (dist. to bldg.) | Spatial regime / Airflow | Representativeness | Must | E5.1 | AQDA |
| position | NA | | | | |
| orientation | NA | | | | |
| Radiation shield | NA | | | | |
| Obstacles | Spatial regime / Airflow | Representativeness | Must | E5.2 | AQDA |
| Dripline | Destructive interference | Accuracy | Should / Must * | E5.4 | AQDA |
| Walls, Parapet, etc. | NA | | | | |
| Air flow arc | Spatial regime / Airflow | Representativeness | Must | E5.2 | AQDA |
| Local sources | Destructive interference (NOx sources) | Representativeness | Should | E5.3 | AQDA |
| Flues | (considered local sources) | | | | |
| Traffic | Destructive interference ** | Accuracy | Should ** | E5.3 | AQDA |
| Probe material | Destructive interference | Accuracy | Must | E9 | AQDA |
| Probe residence time | Destructive interference | Accuracy | Must | E9 & QA II | AQDA |
| Inline filter | Operation | Accuracy | NA | QA II | AQDA |
| Station temperature | Operation | Accuracy | NA | QA II | AQDA |

* Should be 20 meters from general dripline of any trees, must be 10 meters from dripline in direction of city center and along summer day-time wind direction

** Acceptable distance from traffic related to volume of traffic and scale of monitoring (see Table 2; 40 CFR 58, Appendix E)

NA - Not Applicable

Rule E#.# - Rule found in 40 CFR 58, Appendix E, Section #.#; QAII - Rule found in ARB QA Manual Volume II

Table 4

Air Monitoring Siting Criteria

Parameter: CO

| Item | Impact | Effect | EPA Status | Rule | Action |
|------------------------------|-----------------------------|--------------------|------------------|------------|--------|
| Ground Cover | NA | | | | |
| Height | Spatial regime sampled * | Representativeness | Must | E4.1 | AQDA |
| Spacing between samplers | NA | | | | |
| Boom length (dist. to bldg.) | Spatial regime / Airflow | Representativeness | Must | E4.1 | AQDA |
| position | NA | | | | |
| orientation | NA | | | | |
| Radiation shield | NA | | | | |
| Obstacles | Spatial regime / Airflow | Representativeness | Must | E4.2 | AQDA |
| Dripline | Spatial regime / Airflow ** | Representativeness | Should / Must ** | E4.4 | ** |
| Walls, Parapet, etc. | NA | | | | |
| Air flow arc | Spatial regime / Airflow | Representativeness | Must | E4.2 | AQDA |
| Local sources | NA | | | | |
| Flues | NA | | | | |
| Traffic | Spatial scale *** | Representativeness | Must | E4.3 | AQDA |
| Probe material | Destructive interference | Accuracy | Must | E9 | AQDA |
| Probe residence time | Destructive interference | Accuracy | Must | E9 & QA II | AQDA |
| Inline filter | Operation | Accuracy | NA | QA II | AQDA |
| Station temperature | Operation | Accuracy | NA | QA II | AQDA |

* Height of inlet depends on scale of monitoring (see 40 CFR 58, Appendix E, Section 4.0)

** Middle and neighborhood scale - trees should not be between CO source and sampler - Warning

- must be at least 10 meters from trees that extend at least 5 m above sampler and are in the direction of a road - AQDA

Microscale - no trees should be located between the sampler and a road - Warning

*** Acceptable distance from traffic related to volume of traffic and scale of monitoring (see Table 1; 40 CFR 58, Appendix E)

NA - Not Applicable

Rule E#.# - Rule found in 40 CFR 58, Appendix E, Section #.#; QAII - Rule found in ARB QA Manual Volume II

Table 5

Air Monitoring Siting Criteria

Parameter : NO2

| Item | Impact | Effect | EPA Status | Rule | Action |
|------------------------------|--------------------------|--------------------|-----------------|------------|--------|
| Ground Cover | NA | | | | |
| Height | Spatial regime sampled | Representativeness | Must | E6.1 | AQDA |
| Spacing between samplers | NA | | | | |
| Boom length (dist. to bldg.) | Spatial regime / Airflow | Representativeness | Must | E6.1 | AQDA |
| position | NA | | | | |
| orientation | NA | | | | |
| Radiation shield | NA | | | | |
| Obstacles | Destructive interference | Accuracy | Must | E6.2 | AQDA |
| Dripline | Destructive interference | Accuracy | Should / Must * | E6.4 | AQDA |
| Walls, Parapet, etc. | NA | | | | |
| Air flow arc | Spatial regime / Airflow | Representativeness | Must | E6.2 | AQDA |
| Local sources | NA | | | | |
| Flues | NA | | | | |
| Traffic | Spatial scale ** | Representativeness | Must | E6.3 | AQDA |
| Probe material | Destructive interference | Accuracy | Must | E9 | AQDA |
| Probe residence time | Destructive interference | Accuracy | Must | E9 & QA II | AQDA |
| Inline filter | Operation | Accuracy | NA | QA II | AQDA |
| Station temperature | Operation | Accuracy | NA | QA II | AQDA |

* Should be 20 meters from general dripline, for individual trees that protrude above the height of the probe by 5 m or more the sampler must be at least 10 m from dripline

** Acceptable distance from traffic related to volume of traffic and scale of monitoring (see Table 3; 40 CFR 58, Appendix E)

NA - Not Applicable

Rule E#.# - Rule found in 40 CFR 58, Appendix E, Section #.#; QAII - Rule found in ARB QA Manual Volume II

Table 6

Air Monitoring Siting Criteria

Parameter : SO₂

| Item | Impact | Effect | EPA Status | Rule | Action |
|------------------------------|--------------------------|--------------------|-----------------|------------|---------|
| Ground Cover | Possible contamination | Representativeness | Must | E3.1 | AQDA |
| Height | Spatial regime sampled | Representativeness | Must | E3.1 | AQDA |
| Spacing between samplers | NA | | | | |
| Boom length (dist. to bldg.) | Spatial regime / Airflow | Representativeness | Must | E3.1 | AQDA |
| position | NA | | | | |
| orientation | Spatial regime / Airflow | Representativeness | Should | E3.1 | Warning |
| Radiation shield | NA | | | | |
| Obstacles | Spatial regime / Airflow | Representativeness | Must | E3.2 | AQDA |
| Dripline | Destructive interference | Accuracy | Should / Must * | E3.3 | AQDA |
| Walls, Parapet, etc. | Spatial regime / Airflow | Representativeness | Must | E3.2 | AQDA |
| Air flow arc | Spatial regime / Airflow | Representativeness | Must | E3.2 | AQDA |
| Local sources | Possible contamination | Representativeness | Should | E3.2 | Warning |
| Flues | Possible contamination | Representativeness | Should | E3.2 | Warning |
| Traffic | NA | | | | |
| Probe material | Destructive interference | Accuracy | Must | E9 | AQDA |
| Probe resistance time | Destructive interference | Accuracy | Must | E9 & QA II | AQDA |
| Inline filter | Operation | Accuracy | NA | QA II | AQDA |
| Station temperature | Operation | Accuracy | NA | QA II | AQDA |

* Should be 20 meters from general dripline of trees, must be 10 m from dripline if the tree is considered an obstacle

NA - Not Applicable

Rule E#.# - Rule found in 40 CFR 58, Appendix E, Section #.#; QAII - Rule found in ARB QA Manual Volume II

Table 7

Air Monitoring Siting Criteria

Parameter : H2S

| Item | Impact | Effect | EPA Status | Rule | Action |
|------------------------------|--------------------------|--------------------|------------|------------|---------|
| Ground Cover | Possible contamination | Representativeness | NA | NA | Warning |
| Height | Spatial regime sampled | Representativeness | NA | NA | Warning |
| Spacing between samplers | NA | | | | |
| Boom length (dist. to bldg.) | Spatial regime / Airflow | Representativeness | NA | NA | Warning |
| position | NA | | | | |
| orientation | Spatial regime / Airflow | Representativeness | NA | NA | Warning |
| Radiation shield | NA | | | | |
| Obstacles | Spatial regime / Airflow | Representativeness | NA | NA | Warning |
| Dripline | Destructive interference | Accuracy | NA | NA | AQDA |
| Walls, Parapet, etc. | Spatial regime / Airflow | Representativeness | NA | NA | Warning |
| Air flow arc | Spatial regime / Airflow | Representativeness | NA | NA | Warning |
| Local sources | Possible contamination | Representativeness | NA | NA | Warning |
| Fluvs | Possible contamination | Representativeness | NA | NA | Warning |
| Traffic | NA | | | | |
| Probe material | Destructive interference | Accuracy | NA | E9 & QA II | AQDA |
| Probe residence time | Destructive interference | Accuracy | NA | E9 & QA II | AQDA |
| Inline filter | Operation | Accuracy | NA | QA II | AQDA |
| Station temperature | Operation | Accuracy | NA | QA II | AQDA |

* Should be 20 meters from general dripline of trees, must be 10 m from dripline if the tree is considered an obstacle

NA - Not Applicable

Rule E#.# - Rule found in 40 CFR 58, Appendix E, Section #.#; QAII - Rule found in ARB QA Manual Volume II

Table 8

Air Monitoring Siting Criteria

Parameter : CH₄, THC, NMOC, PAMS

| Item | Impact | Effect | EPA Status | Rule | Action |
|------------------------------|---------------------------------|--------------------|-----------------|--------------|--------|
| Ground Cover | NA | | | | |
| Height | Spatial regime sampled | Representativeness | Must | E10.1 & PAMS | AQDA |
| Spacing between samplers | NA | | | | |
| Boom length (dist. to bldg.) | Spatial regime / Airflow | Representativeness | Must | E10.1 & PAMS | AQDA |
| position | NA | | | | |
| orientation | Spatial regime / Airflow | Representativeness | Must | E10.2 & PAMS | AQDA |
| Radiation shield | NA | | | | |
| Obstacles | Spatial regime / Airflow | Representativeness | Must | E10.2 & PAMS | AQDA |
| Dripline | Destructive Interference | Accuracy | Should / Must * | E10.4 & PAMS | AQDA |
| Walls, Parapet, etc. | NA | | | | |
| Air flow arc | Spatial regime / Airflow | Representativeness | Must | E10.2 & PAMS | AQDA |
| Local sources | Contamination / Interference | Representativeness | Must | E10.3 & PAMS | AQDA |
| Flues | (considered Obstacles) | | | | |
| Traffic | Contamination / Interference ** | Representativeness | Must | E10.3 & PAMS | AQDA |
| Probe material | Destructive interference | Accuracy | NA | E9 & QA II | AQDA |
| Probe residence time | Destructive interference | Accuracy | NA | E9 & QA II | AQDA |
| Inline filter | Operation | Accuracy | NA | QA II | AQDA |
| Station temperature | Operation | Accuracy | NA | QA II | AQDA |

* Should be 20 meters from general dripline of any trees, must be 10 meters from dripline in direction of urban core or other area of maximum ozone precursors in the direction of the predominant winds

** Acceptable distance from traffic related to volume of traffic and scale of monitoring (see Table 2.2; PAMS)

NA - Not Applicable

Rule PAMS - Rule found in Photochemical Assessment Monitoring Stations Guidelines, Section 2.3.3; QAII - Rule found in ARB QA Manual Volume II

Rule E#.# - Rule found in 40 CFR 58, Appendix E, Section #.#

Table 9

Air Monitoring Siting Criteria

Parameter : Wet Acid Deposition

| Item | Impact | Effect | EPA Status | Rule | Action |
|--------------------------|---------------------------------|--------------------|------------|-------|---------|
| Ground Cover | Possible contamination | Accuracy | NA | QA II | AQDA |
| Height | Spatial regime sampled | Representativeness | NA | QA II | Warning |
| Spacing between samplers | Spatial regime and interference | Representativeness | NA | QA II | Warning |
| Boom length | NA | | | | |
| position | NA | | | | |
| orientation | NA | | | | |
| Radiation shield | NA | | | | |
| Obstacles | Interference | Accuracy | NA | QA II | AQDA |
| Dripline | (considered obstacles) | | | | |
| Walls, Parapet, etc. | (considered obstacles) | | | | |
| Air flow arc | NA | | | | |
| Local sources | Possible contamination | Accuracy | NA | QA II | AQDA |
| Flues | Possible contamination | Accuracy | NA | QA II | AQDA |
| Traffic | Possible contamination | Accuracy | NA | QA II | AQDA |
| Probe material | NA | | | | |
| Probe residence time | NA | | | | |
| Inline filter | NA | | | | |
| Station temperature | NA | | | | |

NA - Not Applicable

Rule QA II - Rule found in ARB QA Manual Volume II

Table 10

Air Monitoring Siting Criteria

Parameter : Dry Acid Deposition

| Item | Impact | Effect | EPA Status | Rule | Action |
|--------------------------|---------------------------------|--------------------|------------|-------|---------|
| Ground Cover | NA | | | | |
| Height | Spatial regime sampled | Representativeness | NA | QA II | Warning |
| Spacing between samplers | Spatial regime and interference | Accuracy | NA | QA II | AQDA |
| Boom length | NA | | | | |
| position | NA | | | | |
| orientation | NA | | | | |
| Radiation shield | NA | | | | |
| Obstacles | Interference | Representativeness | NA | QA II | Warning |
| Dripline | Destructive interference | Accuracy | NA | QA II | AQDA |
| Walls, Parapet, etc. | Spacial Regime / Airflow | Representativeness | NA | QA II | Warning |
| Air flow arc | Spatial regime sampled | Representativeness | NA | QA II | Warning |
| Local sources | Possible contamination | Representativeness | NA | QA II | Warning |
| Flues | Possible contamination | Representativeness | NA | QA II | Warning |
| Traffic | Possible contamination | Representativeness | NA | QA II | Warning |
| Probe material | NA | | | | |
| Probe residence time | NA | | | | |
| Inline filter | NA | | | | |
| Station temperature | NA | | | | |

NA - Not Applicable

Rule, QA II - Rule found in ARB QA Manual Volume II

Table 11

Air Monitoring Siting Criteria

Parameter : Toxics (Gaseous; 910, 910A, 920)

| Item | Impact | Effect | EPA Status | Rule | Action |
|--------------------------|------------------------------|--------------------|------------|-------|---------|
| Ground Cover | NA | | | | |
| Height | Spatial regime sampled | Representativeness | NA | QA II | Warning |
| Spacing between samplers | NA | | | | |
| Boom length | NA | | | | |
| position | NA | | | | |
| orientation | NA | | | | |
| Radiation shield | NA | | | | |
| Obstacles | Interference / Contamination | Accuracy | NA | QA II | AQDA |
| Dripline | (considered obstacles) | Accuracy | NA | QA II | AQDA |
| Walls, Parapet, etc. | Spatial regime sampled | Representativeness | NA | QA II | Warning |
| Air flow arc | Spatial regime sampled | Representativeness | NA | QA II | Warning |
| Local sources | Possible contamination | Representativeness | NA | QA II | Warning |
| Flues | Possible contamination | Representativeness | NA | QA II | Warning |
| Traffic | Possible contamination | Representativeness | NA | QA II | Warning |
| Probe material | Interference | Accuracy | NA | QA II | AQDA |
| Probe residence time | Interference | Accuracy | NA | QA II | AQDA |
| Inline filter | Operation | Operation | NA | QA II | Warning |
| Station temperature | Operation | Accuracy | NA | QA II | AQDA |

NA - Not Applicable

Rule QA II - Rule found in ARB QA Manual Volume II

Table 12

Air Monitoring Siting Criteria

Parameter: Toxics (Particulate: 920)

| Item | Impact | Effect | EPA Status | Rule | Action |
|--------------------------|---------------------------------|--------------------|------------|-------|---------|
| Ground Cover | Possible contamination | Representativeness | NA | QA II | Warning |
| Height | Spatial regime sampled | Representativeness | NA | QA II | Warning |
| Spacing between samplers | Spatial regime and interference | Accuracy | NA | QA II | AQDA |
| Boom length | NA | | | | |
| position | NA | | | | |
| orientation | NA | | | | |
| Radiation shield | NA | | | | |
| Obstacles | Spatial regime / Airflow | Representativeness | NA | QA II | Warning |
| Dripline | Destructive interference | Accuracy | NA | QA II | AQDA |
| Walls, Parapet, etc. | Spatial regime / Airflow | Representativeness | NA | QA II | Warning |
| Air flow arc | Spatial regime / Airflow | Representativeness | NA | QA II | Warning |
| Local sources | Possible contamination | Representativeness | NA | QA II | Warning |
| Flues | Possible contamination | Representativeness | NA | QA II | Warning |
| Traffic | Possible contamination | Representativeness | NA | QA II | Warning |
| Probe material | NA | | | | |
| Probe residence time | NA | | | | |
| Inline filter | NA | | | | |
| Station temperature | NA | | | | |

* Should be 20 meters from general dripline of trees, must be 10 m from dripline if the tree is considered an obstacle

NA - Not Applicable

Rule QA II - Rule found in ARB QA Manual Volume II

Table 13

Air Monitoring Siting Criteria

Parameter : Temperature and Relative Humidity

| Item | Impact | Effect | EPA Status | Rule | Action |
|--------------------------|------------------------|--------------------|------------|---------------|---------|
| Ground Cover | Interference | Accuracy | Must | Vol IV, QA II | AQDA |
| Height | Spatial regime sampled | Representativeness | Should | Vol IV, QA II | Warning |
| Spacing between samplers | NA | | | | |
| Boom length | Interference | Accuracy | Must | Vol IV, QA II | AQDA |
| position | Interference | Accuracy | Should | Vol IV, QA II | AQDA |
| orientation | Interference | Accuracy | Should | Vol IV, QA II | AQDA |
| Radiation shield | Interference | Accuracy | Should | Vol IV, QA II | AQDA |
| Obstacles | Spatial regime sampled | Representativeness | Should | Vol IV, QA II | Warning |
| Dripline | (considered obstacles) | | | | |
| Walls, Parapet, etc. | (considered obstacles) | | | | |
| Air flow arc | (considered obstacles) | | | | |
| Local sources | Interference | Representativeness | NA | Vol IV, QA II | Warning |
| Flues | Interference | Representativeness | NA | Vol IV, QA II | Warning |
| Traffic | NA | | | | |
| Probe material | NA | | | | |
| Probe residence time | NA | | | | |
| Inline filter | NA | | | | |
| Station temperature | NA | | | | |

NA - Not Applicable

Rule Vol IV - Rule found in EPA Quality Assurance Handbook for Air Pollution Measurement Systems, Volume IV

Rule QA II - Rule found in ARB QA Manual Volume II

Table 14

Air Monitoring Siting Criteria

Parameter : Wind Speed and Direction

| Item | Impact | Effect | EPA Status | Rule | Action |
|--------------------------|------------------------|--------------------|------------|--------------------|---------|
| Ground Cover | NA * | | | | |
| Height | Spatial regime sampled | Representativeness | Should | PSD, Vol IV, QA II | Warning |
| Spacing between samplers | NA | | | | |
| Boom length | Interference | Accuracy | Should | PSD, Vol IV, QA II | AQDA |
| position | Interference | Accuracy | Should | PSD, Vol IV, QA II | AQDA |
| orientation | Interference | Accuracy | Should | PSD, Vol IV, QA II | AQDA |
| Radiation shield | NA | | | | |
| Obstacles | Interference | Accuracy | Should | PSD, Vol IV, QA II | AQDA |
| Dripline | (considered obstacles) | | | | |
| Walls, Parapet, etc. | (considered obstacles) | | | | |
| Air flow arc | Interference | Accuracy | Should | QA II | AQDA |
| Local sources | NA | | | | |
| Flues | NA | | | | |
| Traffic | NA | | | | |
| Probe material | NA | | | | |
| Probe residence time | NA | | | | |
| Inline filter | NA | | | | |
| Station temperature | NA | | | | |

* Avoid complex terrain

NA - Not Applicable

Rule PSD - Rule found in EPA Ambient Monitoring Guidelines for Prevention of Significant Deterioration

Rule Vol IV - Rule found in EPA Quality Assurance Handbook for Air Pollution Measurement Systems, Volume IV

Rule QA II - Rule found in ARB QA Manual Volume II

Table 15

Air Monitoring Siting Criteria

Parameter : Solar Radiation

| Item | Impact | Effect | EPA Status | Rule | Action |
|--------------------------|------------------------|--------------------|------------|---------------|---------|
| Ground Cover | NA | | | | |
| Height | NA | | | | |
| Spacing between samplers | NA | | | | |
| Boom length | NA | | | | |
| position | NA | | | | |
| orientation | NA | | | | |
| Radiation shield | NA | | | | |
| Obstacles (shadows) | Interference | Representativeness | Should | Vol IV, QA II | Warning |
| Dripline | NA | | | | |
| Walls, Parapet, etc. | (considered obstacles) | | | | |
| Air flow arc | NA | | | | |
| Local sources * | Interference | Representativeness | Should | Vol IV, QA II | Warning |
| Flues | NA | | | | |
| Traffic | NA | | | | |
| Probe material | NA | | | | |
| Probe residence time | NA | | | | |
| Inline filter | NA | | | | |
| Station temperature | NA | | | | |

* light colored walls, reflective surfaces, lights

NA - Not Applicable

Rule PSD - Rule found in EPA Ambient Monitoring Guidelines for Prevention of Significant Deterioration

Rule Vol IV - Rule found in EPA Quality Assurance Handbook for Air Pollution Measurement Systems, Volume IV

Rule QA II - Rule found in ARB QA Manual Volume II

SITE SURVEY REPORT

Siting Information

| | | | |
|--------------|---------------|-------------|--------------|
| Site Name: | Audit Date: | Latitude: | Site Report: |
| ARB Number: | Auditors: | Longitude: | Site Photos: |
| AIRS Number: | | Elevation: | |
| Agency: | Site Contact: | Site Phone: | |

General Siting Conditions

| | | | | |
|--|--|---------------------------------|---------------------|-----------------------|
| Station Temperature Controlled: Recorded: Inside: | Traffic description: distance: count: | Dominant Influence category: | QA Plan: | Probe/Manifold Clean: |
| | | Topography Site: Region: | Air Flow Arc: | Schedule: |
| Meteorology Collocated: Shadowing: Boom Orientation: Temp. Rad. Shield Asp.: | Non-vehicular Local Sources Description: Distance: Direction: | | Urbanization: | Site Survey Complete: |
| | | Ground Cover: | Logbook Up to Date: | |
| | | | QA Manual | |
| | | | Approved: | |
| | | | Agency: | |

Action Items

| |
|--|
| |
|--|

SITE SURVEY REPORT (Cont'd.)

| | Instrument Type | Purpose | Objective | Scale | Height Above | | Sampler Spacing | Manual Available | Inst. Log. Maint'd. & Avail. | In Line Filter Change Date | Cal. Gas Cert. Date |
|---------------|--------------------|---------|-----------|-------|--------------|----------|--------------------|---------------------|---------------------------------|-------------------------------|------------------------|
| | | | | | Ground | Platform | | | | | |
| O3 | | | | | | | | | | | |
| SO2 | | | | | | | | | | | |
| NO2 | | | | | | | | | | | |
| CO | | | | | | | | | | | |
| H2S | | | | | | | | | | | |
| CH4 | | | | | | | | | | | |
| THC | | | | | | | | | | | |
| NMHC | | | | | | | | | | | |
| PM10 | | | | | | | | | | | |
| PM10 Colloc. | | | | | | | | | | | |
| PM2.5 | | | | | | | | | | | |
| PM2.5 Colloc. | | | | | | | | | | | |
| PM2.5 Spec. | | | | | | | | | | | |
| TSP | | | | | | | | | | | |
| TSP Colloc. | | | | | | | | | | | |
| Lead | | | | | | | | | | | |
| Dichot | | | | | | | | | | | |
| TEOM | | | | | | | | | | | |
| BAM | | | | | | | | | | | |
| Temp. | | | | | | | | | | | |
| %RH | | | | | | | | | | | |
| Baro | | | | | | | | | | | |
| WS HORIZ. | | | | | | | | | | | |
| WS VERTICAL | | | | | | | | | | | |
| WD | | | | | | | | | | | |
| Solar | | | | | | | | | | | |
| Rain Gauge | | | | | | | | | | | |
| Toxics 920 | | | | | | | | | | | |
| Carbonyl 925 | | | | | | | | | | | |
| NMOC 910 | | | | | | | | | | | |
| Wet/Dry Acid | | | | | | | | | | | |
| AISI Tape | | | | | | | | | | | |
| Nephelometer | | | | | | | | | | | |

SITE SURVEY REPORT (Cont'd.)

| | Calibration | | Cal. Equip. Cert. Date | Description of Obstacle | Dist./Direct. to Obstacle | Height above Inlet | Distance to Walls, etc. | Distance to Dripline | Residence Time |
|---------------|-------------|-----------|---------------------------|----------------------------|------------------------------|-----------------------|----------------------------|-------------------------|-------------------|
| | Current | Cal. Date | | | | | | | |
| O3 | | | | | | | | | |
| SO2 | | | | | | | | | |
| NO2 | | | | | | | | | |
| CO | | | | | | | | | |
| H2S | | | | | | | | | |
| CH4 | | | | | | | | | |
| THC | | | | | | | | | |
| NMHC | | | | | | | | | |
| PM10 | | | | | | | | | |
| PM10 Colloc. | | | | | | | | | |
| PM2.5 | | | | | | | | | |
| PM2.5 Colloc. | | | | | | | | | |
| PM2.5 Spec. | | | | | | | | | |
| TSP | | | | | | | | | |
| TSP Colloc. | | | | | | | | | |
| Lead | | | | | | | | | |
| Dichot | | | | | | | | | |
| TEOM | | | | | | | | | |
| BAM | | | | | | | | | |
| Temp. | | | | | | | | | |
| %RH | | | | | | | | | |
| Baro. | | | | | | | | | |
| WS Horiz. | | | | | | | | | |
| WS Vertical | | | | | | | | | |
| WD | | | | | | | | | |
| Solar | | | | | | | | | |
| Rain Gauge | | | | | | | | | |
| Toxics 920 | | | | | | | | | |
| Carbonyl 925 | | | | | | | | | |
| NMOC 910 | | | | | | | | | |
| Wet/Dry Acid | | | | | | | | | |
| AISI Tape | | | | | | | | | |
| Nephelometer | | | | | | | | | |

SITE SURVEY REPORT (Cont'd.)

Probe Residence Time Information

| | Pollutant: | | | | | |
|------------|------------|----------|------------------------|------------------------|------------------------|------------------------|
| | Probe | Manifold | Manifold to Instrument | Manifold to Instrument | Manifold to Instrument | Manifold to Instrument |
| Material | | | | | | |
| ID (mm) | | | | | | |
| Length (m) | | | | | | |
| Flow (Q) | | | | | | |
| Time | | | | | | |
| | | | | | | |

Total
Residence
Time

Pull-down Options

- Dominant Influence** : vehicular/industrial
- Topography** : level/valley/hilly/mountainous
- Urbanization** : city center/suburban/rural/remote
- Cleaning Schedule** : weekly/bi-weekly/monthly/semi-annually/annually
- Purpose** : NAMS/SLAMS/PAMS/PSD/Special Purpose
- Objective** : background conc./highest conc./representative conc./maximum population/source impact/other
- Scale** : micro/middle/neighborhood/urban/regional

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